STUDIES ON THE TAXONOMY AND SOME ASPECTS OF BIOLOGY OF THE FISHES OF THE FAMILY BALISTIDAE FROM THE INDIAN SEAS

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By

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CERTIFICATE

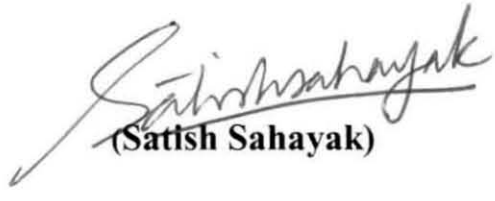
This is to certify that this Thesis is an authentic record of the work carried out by **Mr. Satish Sahayak,** under my supervision and guidance in partial fulfilment of the requirement for the degree of ***Doctor of Philosophy*** of the University of Kerala and that no part thereof has been presented for any other degree or diploma.

Cochin
August 2003

V. Sriramachandra Murty
(Supervising guide)

DECLARATION

I hereby declare that this Thesis entitled **"STUDIES ON THE TAXONOMY AND SOME ASPECTS OF BIOLOGY OF THE FISHES OF THE FAMILY BALISTIDAE FROM THE INDIAN SEAS"** is a *bona fide* record of research carried out by me under the supervision and guidance of Dr. V. Sriramachandra Murty, Head Demersal Fisheries Division (Retd.), Central Marine Fisheries Research Institute, Cochin, for the partial fulfilment of the requirements for the degree of Doctor of Philosophy of the University of Kerala and that no part of this has been presented for any degree, diploma or any other similar title of any University.



(Satish Sahayak)

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Dedicated to my Parents

CONTENTS

Chapter 1

Introduction

1. INTRODUCTION

The fishes of the family Balistidae popularly known as trigger fishes (locally called *Moori* in Malayalam and *Klathi* in Tamil) are cosmopolitan in distribution. Most of the species are known from the Indian and the Pacific Oceans, though certain species are restricted to particular regions (Randall and Klausewitz, 1973 and Smith and Heemstra, 1986). In India, these fishes are abundant in the Gulf of Kutch, off Maharashtra coast (Malwan), off Kerala (Quilon bank), Palk Bay and Andaman and Lakshadweep Islands (Day, 1878; Venkataraman and George, 1965; Jones and Kumaran, 1980; Balasubramanian *et. al.*, 1995 and Murty, 2002).

Trigger fishes occupy diverse habitats such as coral reefs, rocky areas, seaweeds, sea grasses and under floating objects in the open oceanic regions (Fedoryako, 1981; Lindberg and Frazer, 1994; Massuti and Renones, 1994 and Stretta *et. al.*, 1998). These fishes show preference to the upper reef edge of the outer slope facing the sea, the outer terrace with surge channels, sandy area inside the lagoon, sandy zone outside the reef towards the sea and the lagoon slope (Klausewitz, 1974). They play an important role in the dispersal of some dominant coral species (Guzman, 1988). In India, the trigger fishes are abundant in the coral reef regions and rocky and seaweed regions (Mahadevan and Nayar, 1967).

Balistids are brightly coloured and many species are distinguished primarily on the basis of colour patterns (Smith and Heemstra, 1986). Most of the species grow up to about 30 cm length, while some species reach more than half a meter in length (Day, 1878).

Trigger fishes contribute only a meagre share to the fishery and are among the most preferred aquarium fishes. Until recently, these fishes were not consumed in India except by some fisher folks of Vizhinjam (Kerala, India) and Colachel (Tamilnadu, India) who developed traditional gear "*Kachal*" to target these fishes for their consumption.

Some species have a small export market. Besides, there is also demand for these fishes as raw material for poultry feed. In order to fulfil these demands increased exploitation and landing of these fishes through hook and line, traps and trawls are taking place along the Wadge Bank and Gulf of Mannar (Balasubramanian *et. al.*, 1995).

The recent trend in exploitation for human consumption and export and the fast increasing demand for these fishes in live condition for aquarium purpose warrant knowledge on taxonomy, distribution in space and time, biological characteristics and stock size to enable formulating strategies for sustaining yields and for addressing the issues of biodiversity conservation. In view of their associations with other organisms like coelenterates, and higher macrophytes, it is also necessary to understand the relationships of these fishes with the assemblages of species belonging to different groups of both plant and animal, particularly because the increasing exploitation will not only effect the trigger fishes but also the ecosystems leading to issues of protection of environments and related aspects.

A survey of the literature on Balistidae reveals that a focused research attention has not been made. There are only a few taxonomic revisions from a few geographical regions that too outside India (Bleeker, 1866; Fraser-Brunner, 1935 and Matsuura, 1981) and only a few studies on the biology (Nzioka, 1978; Lobel and Johannes, 1980; Aiken, 1983; Menezes, 1985; Danson, 1990; Gladstone, 1994 and Kuwamura, 1997 etc.).

Since the Rio de Janeiro summit (1992) and the Convention on Biological Diversity (CBD), increased global concerns are being expressed by different coastal states to the issues pertaining to utilisation, conservation and protection of biodiversity, including marine biodiversity. However, most of the countries particularly the tropical developing countries are not adequately equipped to address these issues in view of the lack of encouragement to this area of research, in the recent past resulting in the decline of taxonomists. While it is important for research institutions to encourage taxonomy in a big way to be able to effectively address the current and emerging issues, it was felt essential to carry out a study of the taxonomy and some aspects of biology of the trigger

fishes of India so that this could form the basic reference for further research in the broader area of marine biodiversity.

1.1 Material and methods

Collections were made from landings of hook and line and trawl at Tuticorin, Kanyakumari (Southeast coast of India), Vizhinjam and Colachel (Southwest coast of India). Each of these centres was visited every month for periods ranging from 3 to 5 days and data on landings, length and other biological characteristics and specimens for taxonomic studies were collected.

Specimens of a few species were collected from trawl and hook and line landings of Mumbai, Veraval, Chennai, Mandapam and Kelakarai. At Minicoy Island (Lakshadweep), collections were made using spear, gillnet and hook and line (Fig. 1).

Data on length, weight and gonad condition were collected from fresh specimens of major species from landing centres. Weight of each fish was recorded in the field using a spring balance. The samples were collected from August 1998 to October 2000.

Figure 1. Map showing the places from where collections were made for the present study

Chapter 2

Taxonomy

2. TAXONOMY

2.1 Introduction

Exploitation of marine living resources for food is an age-old practice but this exploitation was largely restricted to near shore regions in the sea. The improvements in the capabilities of exploitation during the past half a century, have helped in increasing harvests of living resources from the coastal waters as well as deeper regions of the sea. The rapid increase in the human population and the consequent increased demand for protein-rich seafood, have led to the exploitation of marine fisheries resources to their optimum levels in most cases. Fisheries resources being renewable, managing them on a sound scientific basis is essential to harvest maximum sustainable economic yields on a continual basis, year after year. The basis for such a management is knowledge of the dynamics of every species that contribute to the fishery. The tropical seas, however, unlike their counterparts in the temperate regions, are inhabited by a large number of species. In many cases the species live together sharing the same habitat and food. Several families are represented by several genera and several closely resembling species and any non-selective (or the least selective) gear exploits a large number of species in one haul. If these species are not correctly differentiated, there is a likelihood of treating two or more closely resembling species as one species, in detailed biological studies like growth, spawning, fecundity etc., leading to erroneous conclusions. A sound knowledge of the taxonomy of the fishes contributing to the fishery and the capability to identify them to species level correctly therefore plays a vital role. As the biological characteristics are known to be different between species and as they form the basis for studies on stock assessment of exploited resources, the capability to distinguish species effectively is of immense value, without this all species-oriented studies do not lead to any meaningful results. Moreover, in recent years there is increasing concern on the protection of the environment and conservation of biodiversity and the issues of marine biodiversity cannot be addressed effectively without a proper understanding of the species constituting to the biodiversity. This is particularly serious in the tropical ecosystems where a multiplicity of species from lower invertebrates to higher vertebrates inhabits the same ecosystem in certain assemblages. Hence, the value of taxonomic

studies in fisheries research is invaluable; it is a prerequisite for any detailed study on species and ecosystem.

Growth of fish taxonomy in India can be traced back to the late 18th century, when European scientists and British Officers of the East India Company, particularly medical doctors, began to collect and describe Indian fishes. Bloch (1795) is one of the pioneers in the field of taxonomy of Indian fishes.

The nineteenth century saw several publications on Indian fishes. Among them are the publications of Schneider in Bloch and Schneider (1801), Lacepede (1798 - 1803), Hamilton (1822), Cuvier and Valenciennes (1828 – 1849), Sykes (1839), Gunther (1860, 1872, 1880) and several publications of Dr. Day (1865-1877) culminating in the " Fishes of India.... " (Day 1875, 1878) and the "Fauna of British India" (1889).

During the twentieth century, subsequent to Chaudhuri (1912, 1916) and Raj (1916, 1941), the significant taxonomic contributions of Hora and his coworkers (1920-1951) based on collections made during extensive surveys in India and the neighboring countries provide the basis for more intensive studies on different groups/families. Most of these works pertain to freshwater fishes. The reports of the new species of fishes discovered in India were also published in the various journals and the information is scattered. Misra (1962) consolidated the available information on important species and published "An aid to identification of the common commercial fishes of India and Pakistan". Later he continued his work and published in 1976 "The fauna of India and Adjacent countries (Pisces)" in three volumes. Jones and Kumaran (1980) published descriptions of over 600 species of fishes from Lakshadweep. Recently, Talwar and Jhingran (1991a, 1991b) published descriptions of a total of 930 species of inland (fresh and brackishwater) fishes of India, including all species known till date.

As on date, a total of about 2500 species of fish are known from India (Talwar and Jhingran 1991a) of which about 1570 are truly marine. While the work of Talwar and Jhingran (1991a, 1991b) largely fulfils the long felt need of the workers on inland fishes,

a similar treatment on the Indian marine fishes is yet to be made. Consequently the workers, perforce, refer to either the publication of Day (1878), which needs to be updated, or some regional publications (as those of Munro, 1955; Smith and Heemstra, 1986 etc.,), which do not contain all species known from the country till date, resulting in most cases, in inaccurate identifications. While there is an urgent need for a comprehensive publication on Indian marine fishes also, the taxonomic studies carried out in recent years on certain groups have shown that there is considerable scope for work in this area because the earlier species descriptions were made on single or a few specimens and did not take intraspecific variation into account thus leading in certain instances to `recognition' of different stages in the life history of a particular species as belonging to different species (as in the case of *Caranx melampygus* Cuvier and *Caranx stellatus* Smith, see Berry, 1968) or creation of new species on the basis of certain abnormal specimens of a species (*Cirrhinus chaudhryi* Srivastava, 1968) and to a lot of confusion on the identity of the species in many instances. In this connection it is worthwhile to quote the following:

1. Leaders in many fields of biology have acknowledged their total dependence on taxonomy (Mayr, 1969:6)

2. The extent to which progress in ecology depends upon accurate identification, and upon the existence of a sound systematic groundwork for all groups of animals, cannot be too much impressed upon the beginner in ecology. This is the essential basis of the whole thing; without it the ecologist is helpless, and the whole of his work may be rendered useless (Elton, 1947, as cited by Mayr, 1969:6)

There have been very few taxonomic revisions of families or genera of marine fishes of India (flatfishes of different families by Norman, 1927, 1928, 1934 and Menon, 1977; Scombridae by Jones and Silas, 1962a, 1962b, 1962c; Mugilidae by Sarojini, 1962a, 1962b; Clupeioids by Whitehead, 1965, 1973, 1985; Trichiuridae by James, 1967; Leiognathidae by James, 1978; Chirocentridae by Luther, 1968; Mullidae by Thomas, 1969; Sphyraenidae by De Sylva, 1975; Syngnathidae (genus *Hippichthys*) by Dawson, 1976; Scorpaenidae (Choridactylinae) by Eschmeyer 1969; Platycephalidae by Murty, 1982; Callionymidae by Ronald, 1983; Sciaenidae by Lal Mohan, 1972, 1982 and

Trewavas, 1977; genus *Nemipterus* (Nemipteridae) by Russell, 1986. etc.,) resulting in the nonavailability of comprehensive work (of a family or genus) incorporating all species described by and discovered subsequent to Day (1878) which could help workers to carry out their work satisfactorily and without difficulty and to address the research needs in the biodiversity conservation efficiently. Though this problem, to some extent, has been solved by the work of Weber and De Beaufort (1911-1962) and the 'Fish identification sheets' issued by FAO (Fischer and Whitehead, 1974; Fischer and Bianchi, 1984), there is still need to provide adequate descriptions of genera and species of a large number of families such as Balistidae and to sort out nomenclatural issues in many cases.

The fishes of the family Balistidae unlike a large number of other teleosts do not form a major fishery any where along their distribution range. Further, these fishes until very recently were not used for human consumption even at places where they occur in catches regularly. As the major interest in research has been on the commercially important fishes, no significant research effort has been paid to any aspect of these fishes. A large number of research workers starting from Linnaeus (1758) (Linnaeus, 1758; Bloch, 1786; Bonnaterre, 1788; Mungo Park, 1797; Lacepede, 1798; Bloch and Schneider, 1801; Latreille, 1804; Shaw, 1804; Tilesius, 1820; Quoy and Gaimard, 1824; Ruppell, 1828, 1835,1852; Lay and Bennett, 1830; Swainson, 1839; Richardson, 1845, 1846; Bleeker, 1849, 1851, 1852, 1853, 1854, 1856, 1857, 1859, 1860, 1865, 1866; Cantor, 1850; Hollard, 1854; Gray, 1854; Montrouzier-Thiolliere, 1856; Kner, 1865; Gunther, 1866, 1870, 1910; Klunzinger, 1871; Day, 1878, 1888; Jordan and Gilbert 1882; Macleay, 1883; Jordan, 1895; Waite, 1899,1903; Steindachner, 1900; Jordan and Fowler, 1902 ; Jordan and Everman, 1903, 1905; Jordan and Seale, 1906; Everman and Seale, 1907; Jordan and Richardson, 1908, 1910; Snyder, 1912; Weber, 1913; Jordan, 1916; Fowler and Bean, 1922; Jordan, 1924; Herre, 1924, 1926, 1936, 1939; Barnard, 1927; Fowler, 1928; Ducker and Mohr, 1929; Schmidt, 1930; Whitley, 1932, 1937; Gitlay, 1933; Tortonese, 1936; Fraser and Brunner, 1935; Fowler, 1936,1938,1949; Longley, 1941; Blegvad and Loppenthin, 1944; Schutlz, 1943; Smith, 1949; Bohlke, 1953; Munro, 1955; Randall, 1955, 1964; Inger, 1957; Rofen, 1958; Gosline and Brock, 1960; Berry and Bladwin, 1966; David, 1966; Moore, 1967; Randall and Klausewitz, 1973; Randall

et. al.,1978; Fedoryako, 1981; Matsuura, 1980, 1981; Tyler, 1980; Eschmeyer and Herald, 1983; Randall and Steene, 1983; Whitehead *et. al.*, 1986; Robin and Ray, 1986; Smith and Heemstra, 1986; Sazonov and Galaktionova, 1987; Matsuura and Shiobara, 1989; Hutchins, 1997; Randall and Bruce, 1998) carried out taxonomic work from different regions of the world. A review of these works reveals that:

1. The species were described on the basis of one or few specimens, hence did not take into account the possible intraspecific variation with growth,
2. A large number of inconsistencies occur in the nomenclature,
3. A comprehensive taxonomic revision of the family is not available from the Indian ocean region,
4. There has not been any taxonomic research in India after Day (1878),
5. The absence of regional works on these fishes resulted in misidentification of different species by different workers,

A critical study of the available species in the range of their distribution shows that the descriptions were rather cursory depending mainly on colour, shape and such others but did not take into account certain morphological characters (scales, nostrils, ventral flap, pelvic spine etc.) or anatomy, resulting in inadequate definition of species.

So far as the Balistids are concerned, the total lack of taxonomic work has been the stumbling block to the fisheries scientists and fishery managers. However in the recent years there has been some demand for these fishes for human consumption and these fishes have been contributing to seasonal fishery in certain pockets along Indian coasts.

Another issue that has emerged in recent years is the one pertaining to marine biodiversity conservation and management and in this respect top priority attention is given to the coral reef ecosystems which are under the severe threat of degradation and, Balistids are an integral part of the coral reef ecosystems. Without strong taxonomic

database on the various organisms inhabiting the ecosystem, issues pertaining to sustainable utilization of the living resources and biodiversity conservation cannot be effectively addressed.

The present study on the taxonomy of the Balistids of India is not only an attempt to provide adequate descriptions of all known species from the country, but also to sort out various issues relating to genera, nomenclature and synonymies.

2.2 Material and methods

In addition to the collections from Mumbai, Veraval, Chennai, Mandapam, Kilakarai, Tuticorin, Vizhinjam, Colachel, Kanyakumari and Minicoy, specimens in the collections of Zoological Survey of India (ZSI), Kolkatta and those in the reference collection Museum of the Central Marine Fisheries Research Institute (CMFRI) at Cochin and Mandapam were also examined.

Soon after collection, the fresh colour and pigmentation of the specimens were recorded at the landing centre and photographs taken. The specimens were then injected with 5% formalin and brought to the laboratory in containers filled with 5% formalin for detailed studies. In the laboratory, the specimens from different localities were preserved separately and all relevant biometric data taken. After taking the biometric data, the belly was cut open to note the sex.

In taking the meristic and morphometric data, the methodology of Hubbs and Lagler (1958) was followed; all the linear measurements were made in the median longitudinal axis (Fig.2). Examination of the nasal apertures and the counts of lateral line scales, arrangement and morphology of the scales on the cheek, body, abdomen, caudal peduncle and fin rays counts were made under a binocular stereo zoom microscope.

Measurements were made with calipers to the nearest 0.1 mm. The measurements taken are defined as follows:

Standard length : From tip of snout to the caudal fin base. (In case of *Odonus niger*, the lower chin was taken as the anterior most edge)

Head : From tip of snout to the branchial opening.

Depth : The vertical measurement, from the origin of second dorsal to origin of anal.

Predorsal length (I) : From tip of snout to the origin of first dorsal.

Predorsal length (II) : From tip of snout to the origin of the second dorsal.

Preanal length : From tip of snout to the origin of anal fin.

Pectoral : The length of the longest ray of the pectoral.

Base of first dorsal : From origin of first dorsal fin to the end at base.

Base of second dorsal : From origin of second dorsal fin to the end at base.

Base of anal : From origin of anal fin to the end at base.

Caudal peduncle : For the least depth of the caudal peduncle.

Orbit : For horizontal eyed diameter.

Inter orbital : For distance between two eyes.

Snout : From tip of snout to the anterior end of orbit.

Head height : The vertical measurement of head, perpendicular through eye.

Post orbital length : From posterior end of eye to the end of branchial opening.

First dorsal spine : Length of first dorsal spine.

Second dorsal : Length of the longest ray of second dorsal.

Anal : Length of longest ray of anal fin.

For uniformity, pectoral fin rays, gill rakers and, morphology and arrangement of scales on cheek, body, abdomen and caudal peduncle, were recorded from the left side only. The abbreviations of Hubbs and Lagler (1958) were followed for various meristic characters. In the case of Dorsal, it is cited as 'D'. The number of spines are shown in upper case Roman numerals, unbranched rays in lower case Roman numerals and branched rays by Arabic numerals (for example D. III, i, 31-36 means the first dorsal fin has three spines and the second dorsal fin has one unbranched ray and thirty one to thirty six branched rays). The number of Pectoral rays shown as P.i, 11-12, meaning the presence of one unbranched ray on the upper side of the pectoral fin and eleven to twelve branched rays. The count of caudal fin rays includes all the branched rays plus two unbranched rays, one above and the other below. The method of counting scales from origin of the second dorsal to base of anal is shown in Fig.3. A. The anterior and posterior margin of first dorsal spine is described in Fig. 3.A.1. The lateral line is interrupted in some species, consisting of anterior curved portion and the posterior straight portion, in such cases the range of lateral line scales in the anterior portion is given first followed by posterior portion. In most of the species the lateral line is continuous. The teeth and spines in the ventral flap, are described with suitable figures. The scales on cheek, body, abdomen and caudal peduncle were studied using stereo zoom

microscope under different magnification, which ranged from 5x – 20x, (Fig. 3.B); the marked area indicates the position of the scales which were studied.). The nasal apertures were also studied under similar magnifications, the figures of these are presented in the species description of each species. The number of gill rakers present on the C- shaped gill arches is given in Arabic numerals. In trigger fishes, the upper and lower limbs of gill arches cannot be distinguished.

Attempts were made to collect adequate number of specimens of each species. However as already stated, the landings of Balistids are poor and only two species (*Sufflamen fraenatus* and *Zenodon niger*) are common. For the rest of the species only a few specimens could be collected. Hence in the case of seven species, the descriptions were made on the basis of less than thirty specimens.

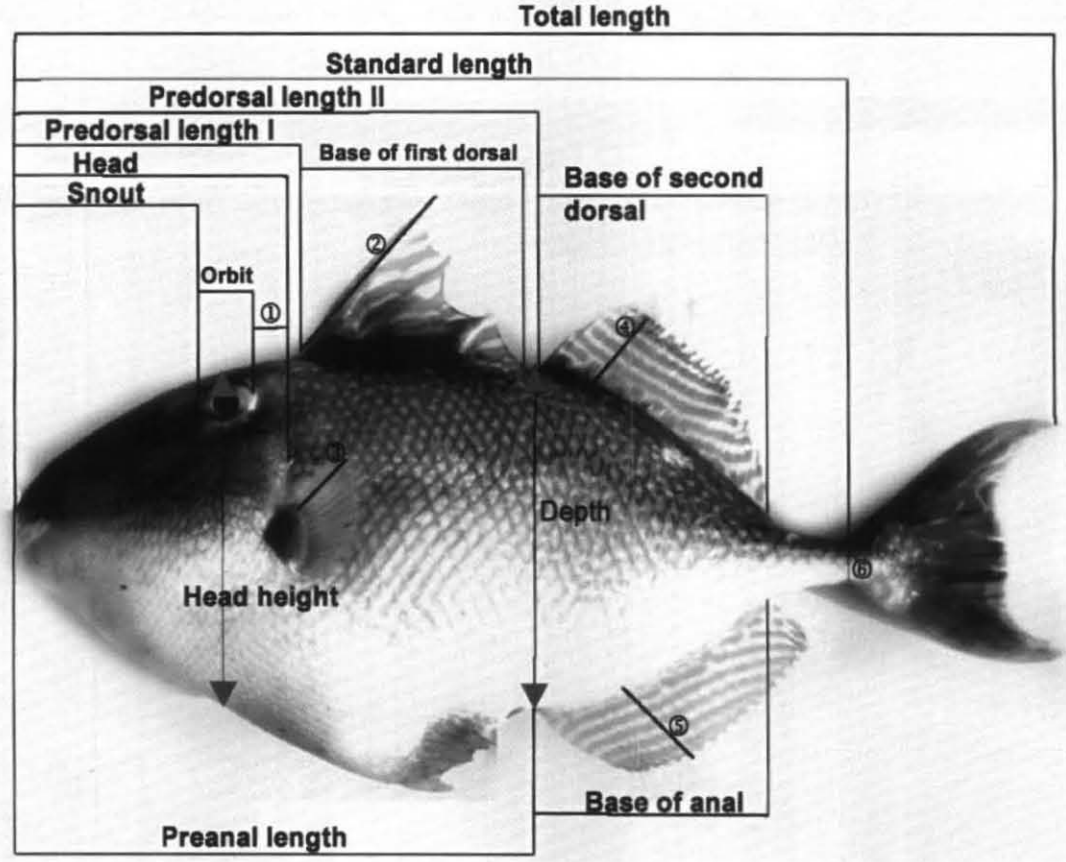
The descriptions of species were made on the basis of specimens collected from one locality and such specimens were indicated in "Material examined". The specimens collected from other localities were used for comparison and supplementing the description and such material was indicated in the "Additional material examined". The frequency distribution of meristic characters together with estimated values of mean, standard deviation and standard error are given for all species.

The relationship between certain body lengths and standard length and between certain dimensions in the head and head length were calculated after ascertaining the type of relationship through a scatter diagram, following the least squares method (Snedecor and Cochran, 1967). The results are presented in the figures and the calculated values of slope and elevation, along with the value of the coefficient of determination (R^2) are shown in the figures for each species. Certain body proportions for each species, are expressed as percentage of standard length and certain proportions in the head expressed as percentage of head (head length) are given in the descriptions; the means are given in parentheses following the range for each proportion, as such studies facilitate comparing and differentiating between closely resembling species of a genus (e.g. Murty 1978) comparison of the stocks of the same species from different localities (Lachner and

Jenkins, 1971). A study of this nature assumes greater importance, since the body proportions are known to vary with growth i.e., the rate of growth of a body part changes with increase in length. Understanding such variations in growth (allometric growth) will help in understanding the intraspecific variations in each species. The frequency distribution of the various meristic characters for each species, is given along with the calculated standard deviation and standard error in the Tables 3-8 at the end of species descriptions.

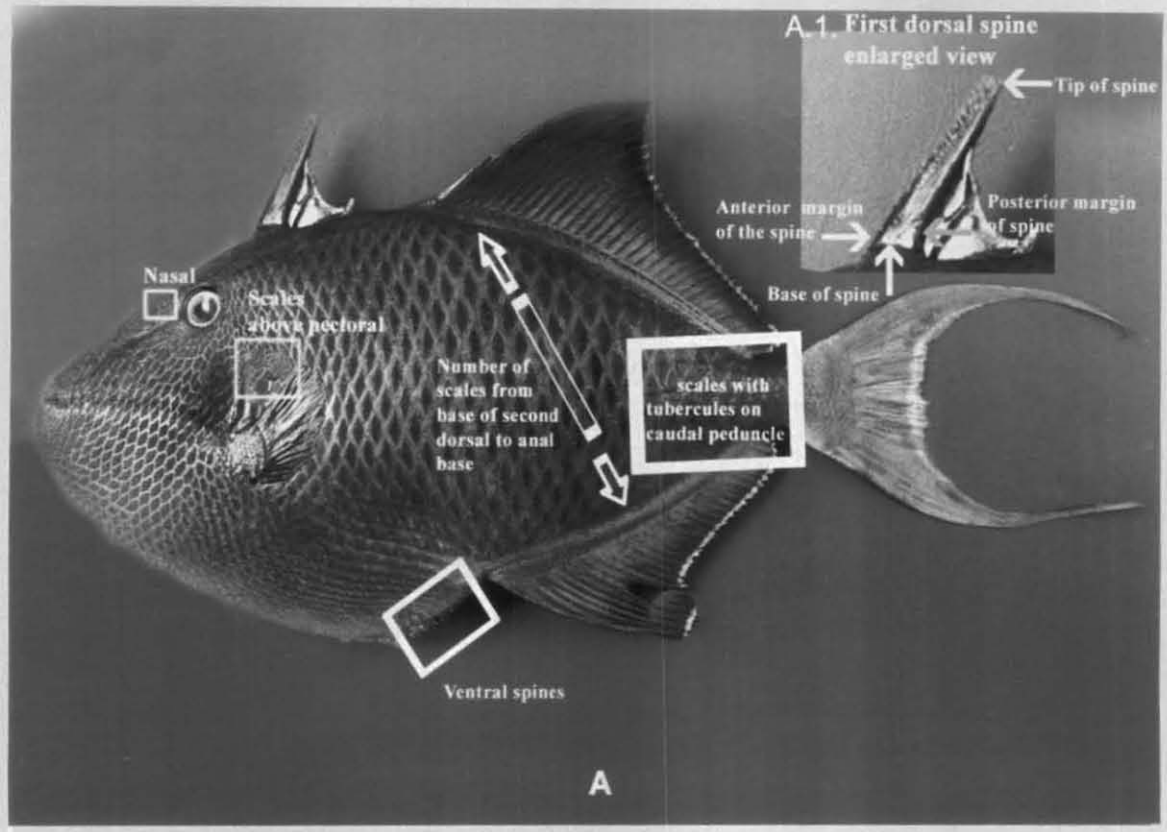
Colour description was always based on fresh specimens. Specimens of certain species were not available in fresh condition; in such cases colour descriptions were made from formalin-preserved specimens.

The known distribution of each species in the world is shown in the World map and the distribution in different localities along Indian coast in the India map. The distribution of each species was collected from the literature. In some cases the authors had mentioned a country name in such cases the Natural History Museum of that country was consulted to find the place of collection. Always the original descriptions of each species and the description by all later authors were consulted for purpose of identification of species. Additionally, as far as possible, the original and subsequent descriptions of the nominal species considered as junior synonyms of valid species by earlier workers were also consulted. The original reference is cited; though the complete list of synonyms is not given, all the references from India and the references of certain nominal species, which are considered as junior synonyms in the present work are given under each species. The International Code of Zoological Nomenclature was constantly consulted; when cited in the text it is referred to as Code. The classification adopted by Nelson (1996) is followed.



① **Post orbital length**
② **First dorsal spine**
③ **Pectoral**
④ **Second dorsal**
⑤ **Anal**
⑥ **Caudal peduncle**

Figure 2. Showing morphometric measurements



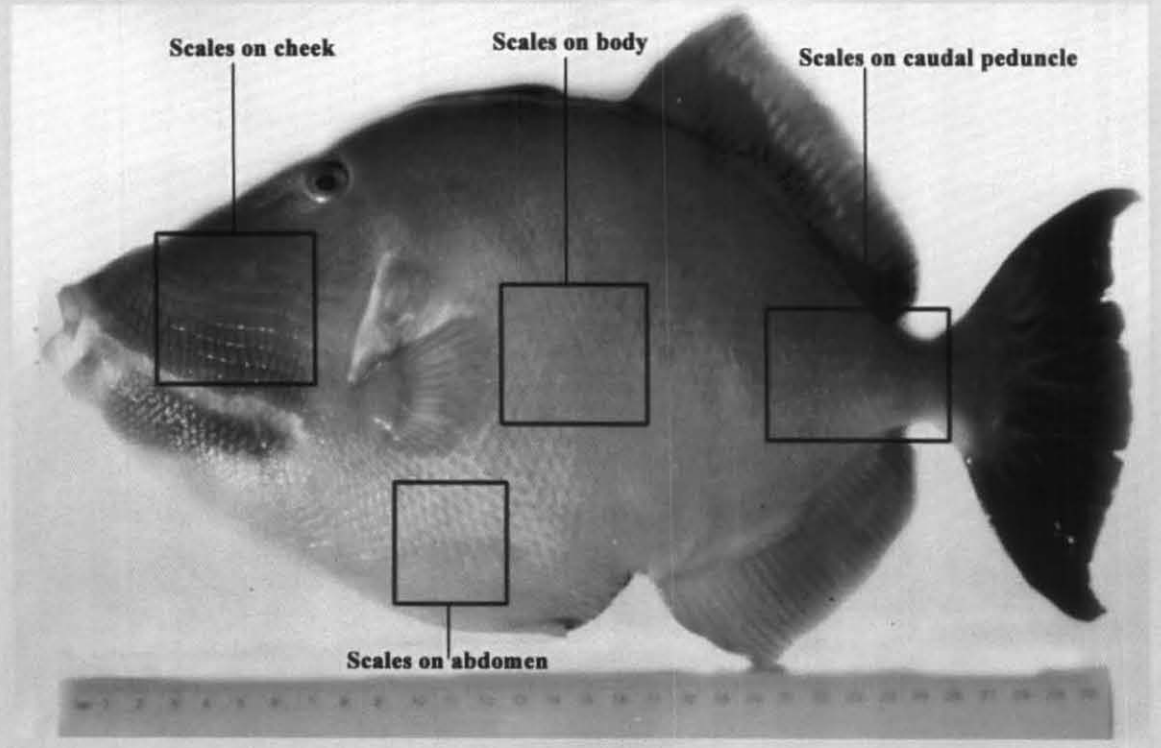


Figure 3 A & B. The meristic and morphlogical characters and postion of scales on cheek, body, abdomen and caudal peduncle used for the description of the species

2.3 External morphology

2.3.1 Introduction

A character is a trait of any organism that can be detected and described. The knowledge of how a set of characters varies among species and other taxa allows the identification of fishes in the first place. From a practical standpoint, it is essential to find easily observable morphological characters for use in identifying species and other taxa. In the fishes of the family Balistidae also, the external morphological characters have been the key source for the identification. The characters like body shape, colour, snout shape, groove before eye, shape of the mouth and its position, type of teeth, fins (number of rays, spines, position of the fin on the body) caudal peduncle shape, presence or absence of spines on it etc. are some of these characters. These characters were recognised by the earlier workers (Lacepede, 1798; Swainson, 1839; Bleeker, 1866; Day, 1889; Weber and Beaufort, 1962; Matsuura, 1981; Smith and Heemstra, 1986), considering their potential in identifying the species, but they were put in different combinations in preparing the keys for identifying the genera and species. Some of these characters were described using ambiguous terminologies making it very difficult to identify a species.

In fishes the scales are an important tool for the purpose of classification and to study the natural history of the fish (Lagler, 1962). The type of the scales in balistid fishes has not been studied in any detail. According to Norman (1975)

> " In the trigger fishes (Balistes) the rough scales covering the body are like those of the Bat-fishes, the basal plate often being rhomboid in shape, with the outer surface roughened or armed with one or more small spines".

Bridge and Boulenger (1989) described the scales of Sclerodermi as an intermediate between ordinary teleostean scales and dermal denticles. The scale has a rhombic basal plate, on which one or more spines are found which may be simple or branched. Many workers described the scales in trigger fishes as: "covered with a granulated coriaceous skin, which is (typically) reticulated" (Swainson, 1839: 324), "*scutis rhomdoideis*" (Bleeker, 1869: 104), "Body covered with more or less imbricate osseous scales"(Weber and De Beaufort, 1962: 278), " covered with strong rough, plate- like scales in regular series" (Smith and Heemstra, 1986: 872), " covered with more or less imbricate plate-like scales, each scale with numerous small nodules and

short longitudinal ridges" (Matsuura,1980: 30). These descriptions however, did not deal with this in detail.

The present work deals with the following external morphological characters, for the first time. These characters are used for the first time in describing the species.

- Shapes of the fins
- Shapes and structure of teeth
- Position, shapes and structures of nasal apertures
- The shape and structure of scales
- Pattern and arrangement of scales of different regions of the body

2.3.2 Material and methods

The samples collected from different stations were used for this study. Descriptions of shape of the teeth and fins were made after proper spreading of the mouth and fins. The shape of the nasals and gill rakers were studied under a stereo zoom microscope. For studying the scales specific area on cheek, body, abdomen and caudal peduncle were selected, (as shown in Fig. 3.B.) and examined under stereo zoom microscope (in magnification of 5x –20x) to study the arrangement, shape and morphology of the scale. Photographs taken during the study were arranged in the figures given at the end of the species description of each species. After this initial study, scales with skin were dissected out and boiled in 5% KOH solution for 5 minutes to separate the scales from tissue and study its shape and arrangement of protuberances. For this the scales were first examined under the stereo zoom microscope and later the scales were treated in 1% osmium tetra oxide and coated with gold in the gold spatter for observing under scanning electron microscope. The observations were made in the Hitachi H600 electron microscope having an H6010-A scanning electron microscope attachment, in magnification of 100x and 200x.

Certain terms used for the description of shape of body, teeth and fins are as follows: rhomboid, oval, rectangular, concave, convex and diamond shaped. For describing scales the following terminologies were used.

1. Anterior margin: - embedded part, anterior margin of the scale (Fig. 4.A)

2. Posterior margin: - exposed part, posterior margin of scale when scale is on fish. (Fig.4.A)
3. Protuberances: - a projection on the scale surface which is ridge-like (Fig.4.B), round (Fig.4.C), spiny antrose or retrose (Fig.4.D & E).

2.3.3 Body shape

The fishes of the family Balistidae have a laterally compressed body. Most of the species have rhomboid or an oval shaped body, where as some have an oval-elongate body.

2.3.4 Second dorsal and anal fin

The unpaired fins, second dorsal and the anal fins display symmetry in these fishes. The shapes are species specific. These fins can be divided into two types based on the height, 1) fins with height less than half the depth of the body; 2) fins with height more than half the depth of the body. The fins belonging to the first category are mostly rectangular, transparent, thick at base thin at the top with different types of outer borders, which range from straight (Fig.5.A), convex (Fig.5.B), elevated at the anterior (Fig.5.C) and wavy edged (Fig.5.D). The rays in these fins are almost of the same length except in some cases the anterior rays are the longest compared to the other rays "elevated at the anterior". In case of "convex" the middle rays are the longest. The fins belonging to the second type have a concave upper border (Fig.5.E) with the base being thick and upper margin thin, in some case wavy, the anterior longest ray gives a appearance of a separate lobe, posterior most rays being less than half the length of the first ray.

2.3.5 Teeth

Balistids have two types of teeth, arranged in two separate rows on the upper jaw. The inner row consisting of three teeth, which is pear shaped to rectangular shaped having thin and sharp edge, placed in the interdental gap of the outer teeth. The outer row has four teeth, the first teeth are flat and projects outside. The lower jaw has a single row of four teeth.

Based on the shape of the first and second teeth of the upper and lower jaws, five types have been identified. They are as follows: 1) The first and the second teeth conical (Dagger shaped), with tips pointed and directed inward (Fig.6.A). 2) The first and the second teeth rectangular with the tip convex towards the inside (Fig.6.B). 3) The first teeth of the upper jaw rectangular but teeth of lower jaw rectangular with a concave tip, the second teeth caniniform and orange coloured (Fig.6.C). 4) The first teeth of upper jaw conical with pointed tip diverging outside, the first teeth of the lower jaw also conical with the tip diverging towards the inside, rest of the teeth of both jaws with a rectangular base, with a conical projection, towards the anterior. (Fig.6.D). 5) All the teeth of upper jaw rectangular with serrated edge (Fig.6.E). The teeth of the lower jaw symmetrical to upper jaw, but directed inwards.

2.3.6 Nasal aperture

The nasal apertures – anterior and posterior, are situated in small depression along the anterior border of the eye. The anterior nasal aperture has different shapes, which is species specific but the posterior aperture is similar in all species. Based on the shape of the anterior nasal aperture five types have been identified. 1) Funnel shaped with edges decurved and a lobe towards the posterior (Fig.7.A). 2) Dome shaped with a pore at the tip (Fig.7.B). 3) Tube like with an irregular edge, in some it is a short tube, which is directed forward (Fig.7.C). 4) The anterior nasal aperture has a circular flap bend over the circular opening (Fig.7.D). 5) Dome shaped with a circular opening, guarded by a fleshy cone from inside (Fig.7.E).

2.3.7 Gills

Trigger fishes have 4 pairs of gills, supported on C- shaped branchial arch. The outer most branchial arch possesses gill rakers. Based on the shape they are divided into five types. 1) Slender, hyaline, pointed and elongated (Fig.8.A). 2) Short and conical with pointed tip (Fig.8.B). 3) Blunt with globular protuberances towards inside (Fig.8.C). 4) Pointed with bristles towards the inside (Fig.8.D). 5) Blunt tipped, hyaline, serrated towards the inside (Fig.8.E).

2.3.8 Scales

a) Morphology

In trigger fishes scales on body and caudal peduncle are diamond-shaped where as scales on cheek and abdomen are rhomboid, rectangular, square or round shaped with the round edges. These scales have a dorsal exposed part called posterior margin and a ventral basal plate called anterior margin (Fig.4.A). The anterior margin forms anterior part of the basal plate, which is embedded in the dermis. Based on the position of the scale on the body, the width of the anterior margin varies. It is widest in the scales found on the body and narrowest on the scales on cheek. The posterior margin consists of horizontal or vertical rows of ridges, round protuberances, antrose spines or retrose spines. Arrangement and type are species specific. At the centre of the posterior margin is present the central canal (minute pore). The morphology and arrangement of scales on cheek, body, abdomen and caudal peduncle are described below.

i) Cheek

These scales have "<" shaped anterior margin. The posterior margin is elevated from the anterior margin. The width of the anterior margin is equal to the posterior margin in most of the cases, wherever there is a change, it is mentioned. Cheek scales are of seven types:

Type I

The scales are rhomboid, diamond or rectangular shaped. The anterior margins are "<" or "**L**" shaped, thin and smooth. The width of the anterior margin is half of the posterior margin. The posterior margin is rhomboid and consists of 3-8 vertical rows of round protuberances (Fig.9.A).

Type II

The scales are diamond shaped. The anterior margin is "<" shaped, thin and have horizontal ridges. The posterior margin diamond shaped and consists of 3-5 vertical rows of horizontal ridges (Fig.9.B).

Type III

The scales are round, square, diamond or rectangular shaped. The anterior margin is "<", "[" or "C" shaped, thin at the anterior most edges and thick posteriorly. Width of the anterior margin is twice that of posterior margin. The posterior margin is square, rhomboid or round having round protuberances and transverse ridges, which are arranged in 3 -5 vertical rows. In round scales the posterior margin is not very clearly demarcated (Fig.9.C).

Type IV

The scales are pentagonal, hexagonal or round in shape. The anterior margin is thin "<" or "(" shaped. The posterior margin is rhomboid with "<" or "I" shaped 5-8 vertical rows having horizontal ridges at the anterior first row and round protuberances as well as ridges in subsequent posterior rows (Fig.9.D).

Type V

The scales are diamond or rhomboid shaped, anterior-posteriorly compressed and dorso-ventrally elongated. The anterior margin is thin having horizontal ridges. The width of the anterior margin is half that of the posterior margin. The posterior margin is rhomboid having 3-5 vertical rows of small to large round protuberances (Fig.9.E).

Type VI

Some of the scales are rectangular or rhomboid; few are anterior-posteriorly compressed and dorso-ventrally elongated, have a smooth surface and covered with a thin skin when found on the fishes, especially occupying fleshy groove. The anterior margin is thin. The width of the anterior margin is one-fourth that of the posterior margin. The posterior margin is rhomboid having 1- 4 vertical rows of small round protuberances and ridges; some the scales have a smooth surface with shallow depressions and ridges (Fig.9.F).

Type VII

The scales are diamond, rhomboid, round or triangular. The anterior margin is thin with few ridges. The width of the anterior margin is half that of the posterior margin in some and in others it is one-fourth that of the posterior margin. The

posterior margin is rectangular, square or rhomboid having 3 - 8 vertical rows of round protuberances arranged in "<" or "I" shaped vertical rows. (Fig.9.G).

ii) Body

In body scales, the width of the anterior margin is equal to that of the posterior margin. The anterior margin is "<" shaped. The posterior margin is diamond shaped. Body scales are of five types:

Type I

The anterior margin is thin and smooth. The posterior margin is slightly elevated from the anterior margin and has ridges on the first row with a large round protuberance at the middle of the scale. Round protuberance is arranged in 2-7 vertical rows (Fig.9.H).

Type II

The anterior margin is thick. The posterior margin has 5 - 10 vertical rows of round protuberances; the anterior most rows of round protuberances are small followed by larger protuberances (Fig.9.I).

Type III

The scales are diamond or rectangular shaped with round edges. The anterior margin thick. The posterior margin has 5 - 10 vertical rows of ridges tapering towards the posterior; the anterior most rows of ridges are large (Fig.9.J).

Type IV

The anterior margin is thick. The posterior margin has 3-5 vertical rows of retrose spines (Fig.9.K).

Type V

The anterior margin is thin. The posterior margin is having 3-5 vertical rows of ridges (horizontally placed) (Fig.9.L).

iii) Abdominal

The scales on the abdomen are diamond or rhomboid shaped, with round edges. The anterior margins are "<" shaped, thin anteriorly with smooth surface. The width of anterior margin is equal to that of the posterior margin. The posterior margin is diamond shaped. They are of three types:

Type I

The posterior margin is rhomboid having 3-4 oblique rows of protuberances. The protuberances are either horizontal ridges or ridges which tapers towards the posterior or ridges which tapers towards the anterior or round protuberances. In some the posterior margin has horizontal ridges on the first row, followed by 3-5 rows of round protuberances (Fig.9.M).

Type II

The posterior margin is rhomboid having a round posterior edge. These scales have horizontal ridges on the first row followed by 3-5 oblique rows of round protuberances (Fig.9.N & O).

Type III

The posterior margin is rectangular or square shaped, having 3-5 oblique rows of round protuberances. At the anterio-ventral corner is present a round protuberance slightly larger than the other protuberances (Fig.9. P-R).

iv) Caudal peduncle

Posterior margin slightly elevated from the anterior margin in case of scales on the caudal peduncle. Diamond shaped, with round edges. The anterior margin is smooth, "<" shaped, thin anteriorly and thick posteriorly. The width of anterior margin equal to the width of the posterior margin. The posterior margin is diamond shaped. These scales are of five types:

Type I

The posterior margin has 3-4 rows of horizontal ridges at the middle and 3 -5 horizontal rows of round protuberance on both sides of the ridges (Fig.9.S).

Type II

The posterior margin has 5 - 10 vertical rows of round protuberances; the anterior most row has a large round protuberance at the middle (Fig.9.T).

Type III

The posterior margin has 10 - 20 horizontal rows of ridges with 3- 4 ridges at the centre slightly elevated and at the anterior of these ridges is present a pointed round protuberance (Fig.9.U).

Type IV

The posterior margin has 3-5 vertical rows of round protuberances with the anterior most rows having a ridge at the centre, which tapers towards the anterior (Fig.9.V).

Type V

The posterior margin has 3-5 vertical rows of horizontal ridges tapering towards the posterior and an antrose spine at the middle. Where as in others there are 5-8 horizontal rows of ridges tapering towards the posterior (Fig.9.W).

f) Type VI

The posterior margin is having 3-5 vertical rows of round protuberances. (Fig.9.X).

b) Arrangement

Examination of the scales on cheek, body, abdomen and caudal peduncle revealed that the general pattern of arrangement were similar between species in case of scales on the body, abdomen and caudal peduncle. Arrangement of scales on cheek varies among species.

i) Cheek scale

There are three types of arrangement of scales on cheek:

Type I

The rhomboid scales arranged in vertical rows, anteriorly and obliquely at the posterior (Fig.10.A).

Type II

The rhomboid to square scales is arranged in horizontal rows. The type of scales in horizontal row varies. a) The scales are square at the anterior and rhomboid to rectangular posteriorly. b) The scales are square at the anterior, with some triangular scale in between and rhomboid scale posteriorly. c) The scales are completely rectangular (Fig. 10.B).

Type III

The square and rhomboid scales are arranged in horizontal rows with wide transverse fleshy horizontal grooves (the horizontal grooves also possess rectangular, rhomboid and elongated scales which is completely covered by a thick skin). In this type of arrangement there are three types. a) Scales at the anterior irregular shaped, posteriorly rhomboid with horizontal grooves. b) Scales at the anterior covered by skin, posteriorly 3-5 horizontal rows of square and rectangular scales; in between the posterior rows are present horizontal grooves. c) Scales covered by skin anteriorly, posteriorly horizontal rows of square scales are present with wide horizontal fleshy grooves (Fig.10.C).

i) Body

The diamond scales are arranged in vertical rows (Fig.10.D).

ii) Abdomen

The scales are arranged in oblique rows. There are two types of scales on the abdomen, rhomboid and rectangular (Fig.10.E).

iii) Caudal peduncle

The diamonds shaped scales are arranged in transverse rows (Fig.10.F).

b) Ultra structure

The analysis of the transverse sections of the body scales under the scanning electron microscope revealed that the scale consists of 4 layers, the upper most layer is glassy, just below is a perforated layer, followed by a vascular area consisting of transverse and longitudinal canals; the fourth layer is the thickest and opaque. These four layers are well demarcated at the anterior and middle portions of the posterior margin, but the posterior portion of the posterior margin is highly compressed and the layers not well demarcated (Fig.11.A-F). The gross morphology is very similar to that of the ganoin scale (Sire, 1989). Since peg like extensions are not found in these scales, (which is the character of the ganoin scales) these scales cannot be classified as ganoin. Hence they are classified as palaeoniscoid scales, which are also found in fishes of the family Polypteridae (Bond, 1979). The anterior margins and posterior margins are different characteristically between species.

i) Anterior margin

The anterior margin of the scales are of 5 types, based on the type of protuberances it possess, (ridges, pits, and network of fibres).

Type I (Ridges)

The anterior margin has horizontal ridges, which are arranged in many semicircular rows (Fig.12.A).

Type II (Pits)

The anterior margin has many pits arranged in transverse rows. All the pits have many pores (Fig.12.B).

Type III (Ridges and circular protuberances)

The anterior portion has many round protuberances, with ridges in between. The arrangement varies in some species with horizontal ridges at the anterior part arranged in different layers (placed one above the other) and round protuberances and pits posteriorly (Fig.12.C).

Type IV (Fibre and pits)

The anterior margin has a network of thin fibres. Between these fibres are present many minute pits (Fig.12.D). In some the fibrous network is made up of broad fibres with very few pits, circular and shallow. In few others the fibrous network is marginal but the pits are large and almost circular.

Type V (Round, triangular, ridge like protuberances, grooves and pits)

The anterior margin consists of horizontal ridges and round, triangular protuberances (Fig.12.E). In some the ridges are arranged in semicircular rows and between rows are present shallow grooves.

ii) Posterior margin

The posterior margin is also of four different types. The protuberances of the posterior margin include, horizontal ridges, ridges tapering towards the posterior, retrose spine, round and cones. These protuberances are arranged on the perforated layer.

Type I (Horizontal ridges and pointed conical protuberance)

The posterior margin has horizontal ridges and conical pointed protuberances. The horizontal ridges occupy the anterior row (Fig.12.F).

Type II (Horizontal ridges and retrose spines protuberance)

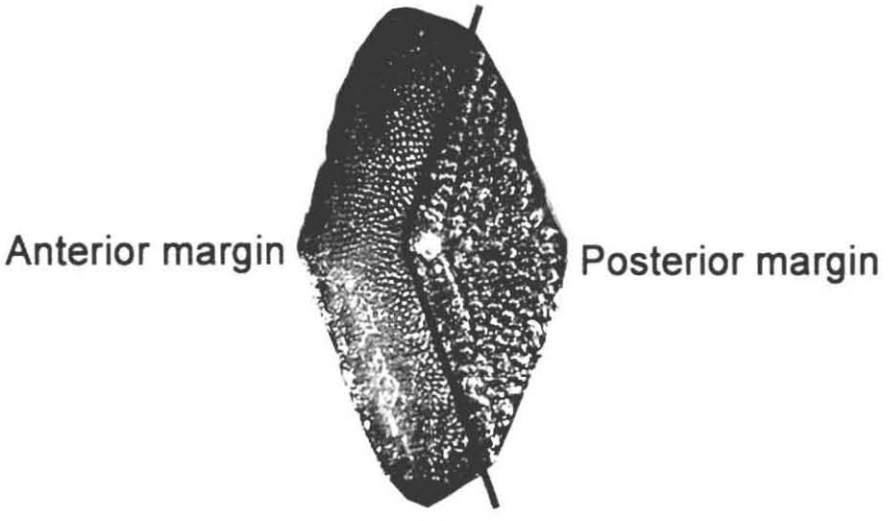
The posterior margin has horizontal ridges and retrose spines; the former occupies the first row (Fig.12.G).

Type III (Horizontal ridges like protuberance)

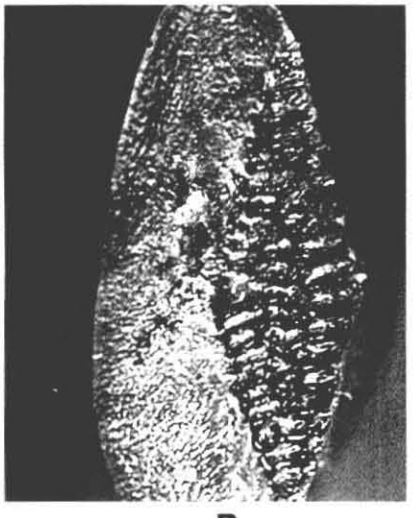
Ridge like protuberances are arranged on few vertical rows (Fig.12.H)

Type IV (Round protuberance)

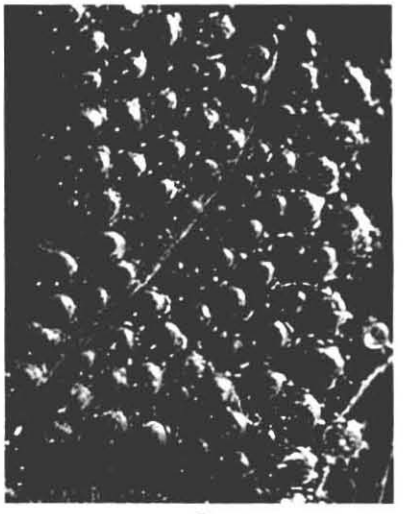
Round protuberances are arranged in 3-5 vertical rows (Fig.12.I)



A
Zenodon niger



B
Melichthys indicus

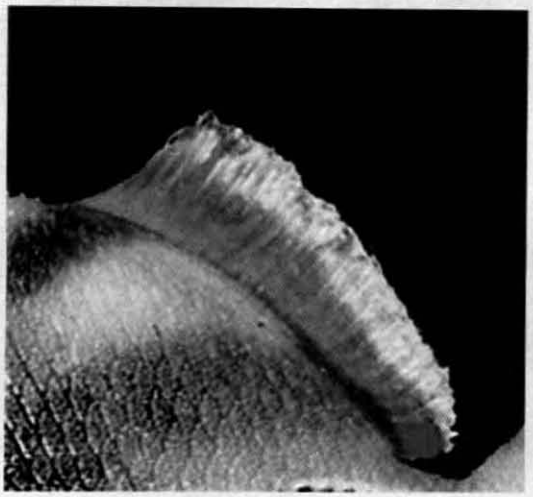


C
Sufflamen fraenatus

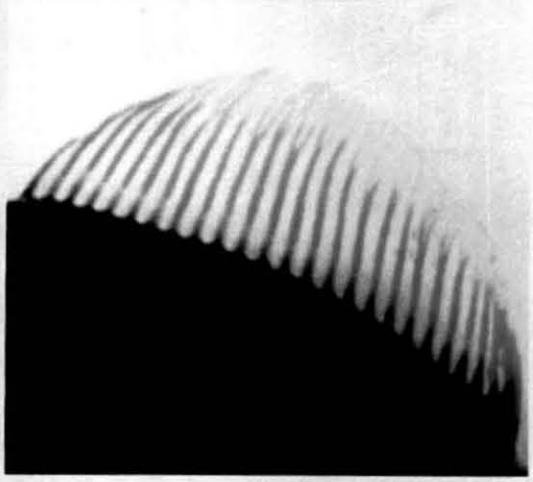
D
Balistapus undulatus

E
Balistapus undulatus

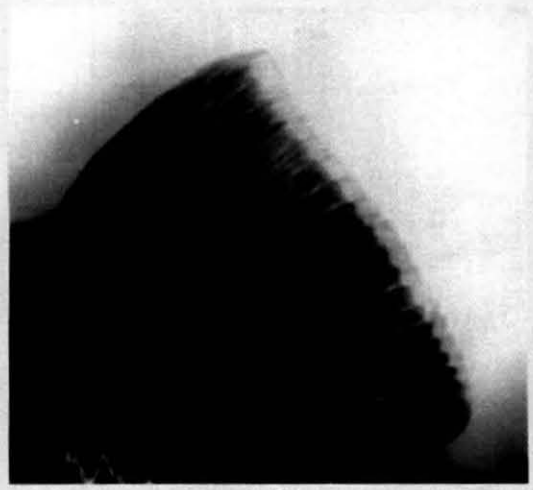
Figure 4. A. The anterior margin and posterior margin of the scale, B. Ridge-like protuberances, C. Round protuberances, D. Antrose spines, E. Retrose spines.



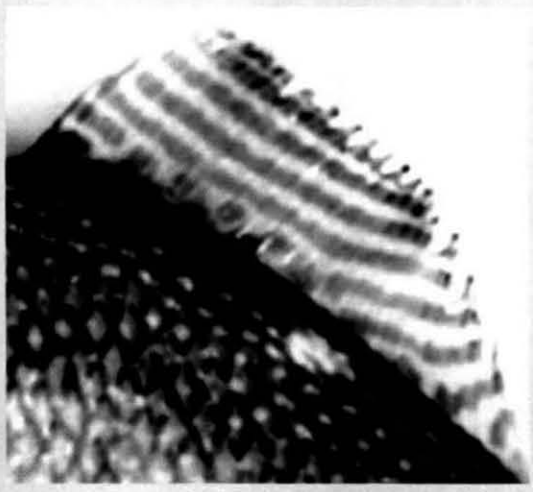
A
Rhinecanthus aculeatus



B
Balistapus undulatus



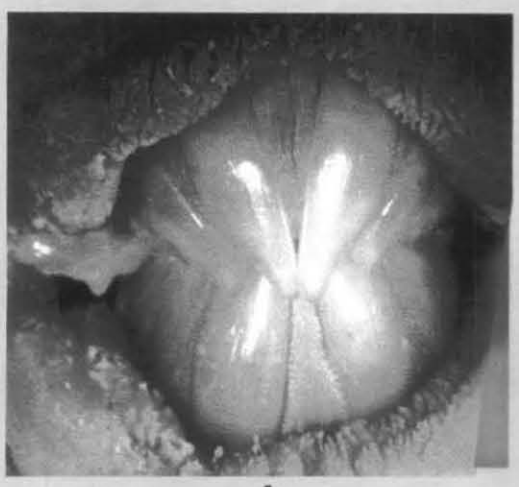
C
Pseudobalistes flavimarginatus



D
Abalistes stellatus

E
Canthidermis macualtus

Figure 5. The second dorsal fin of the fishes of the family Balistidae

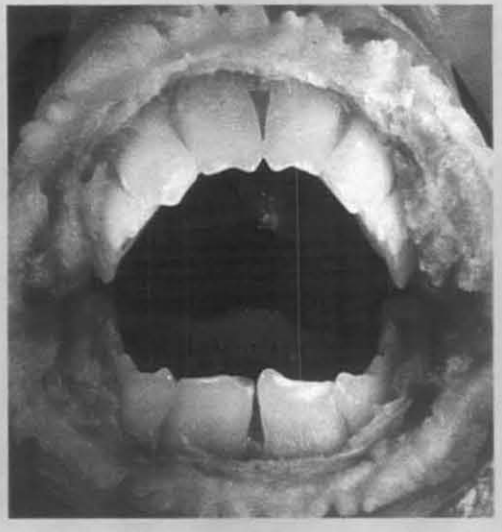


A
Abalistes stellatus

B
Melichthys indicus

C
Zenodon niger

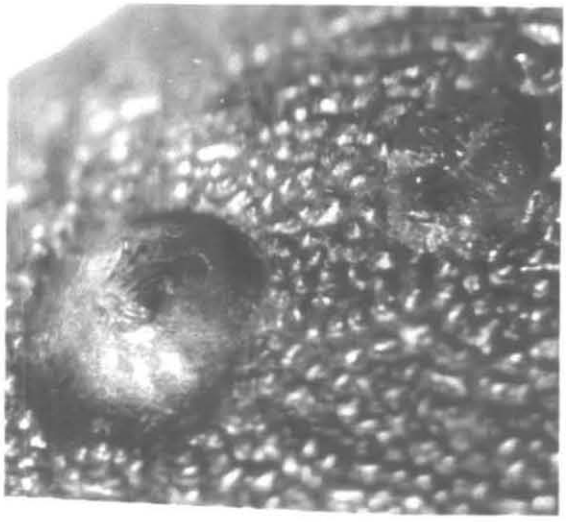
D
Pseudobalistes flavimarginatus



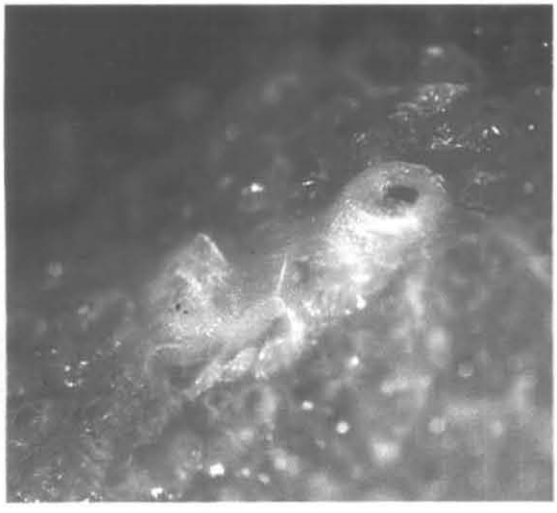
E
Rhinecanthus aculeatus

Figure 6. Teeth pattern in the fishes of the family Balistidae

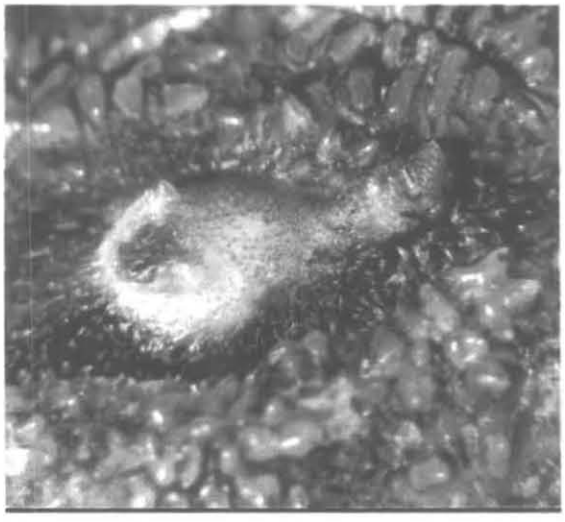
A
Abalistes stellatus



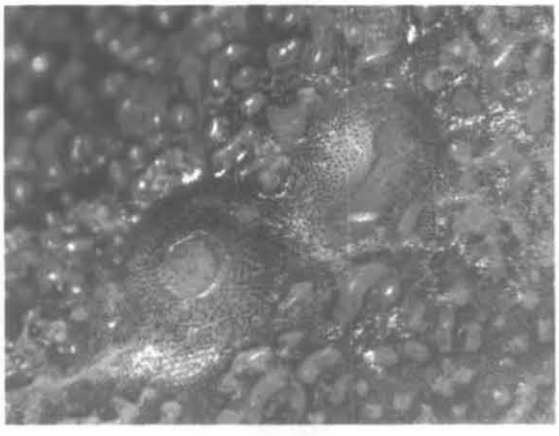
B
Balistapus undulatus



C
Sufflamen chrysopterus

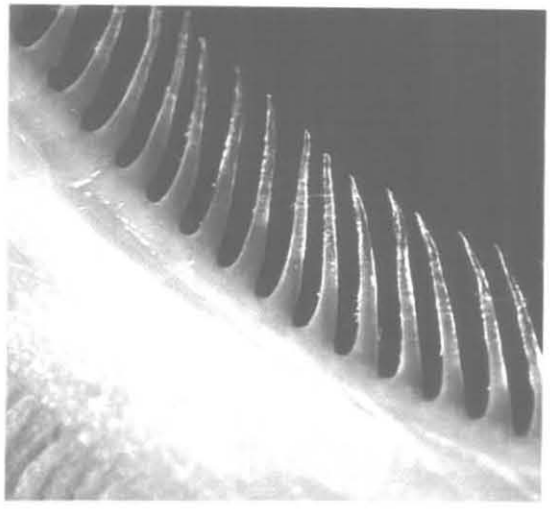


D
Pseudobalistes viridescens

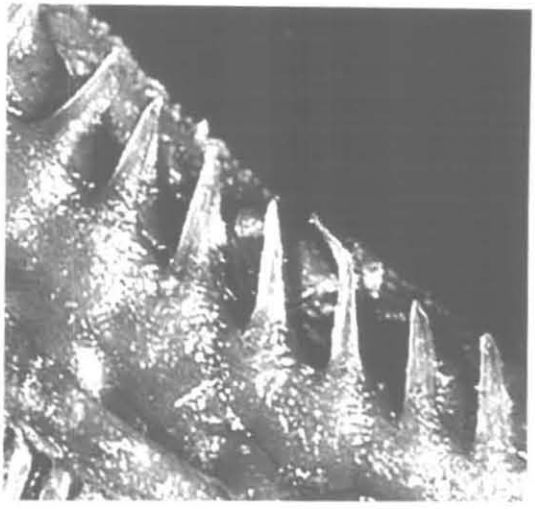


E
Sufflamen fraenatus

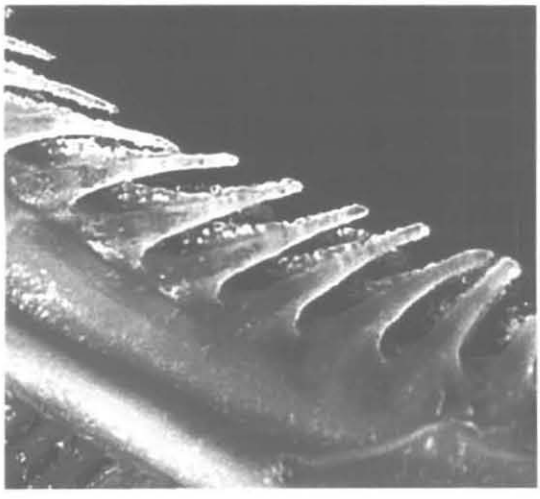
Figure 7. The nasal apertures of the fishes of the family Balistidae



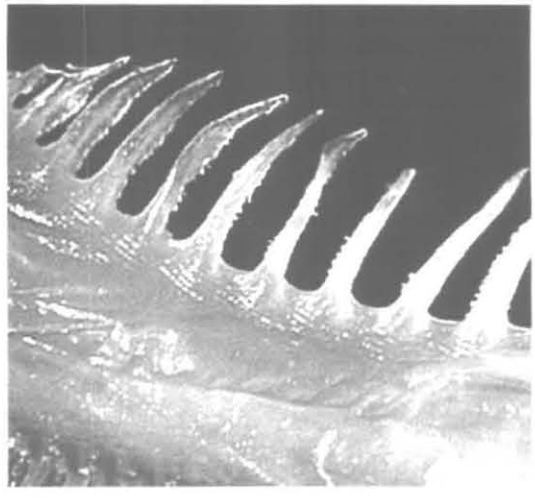
A
Abalistes stellatus



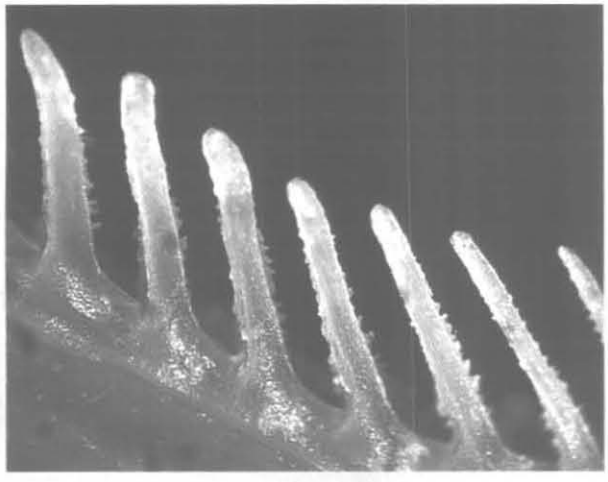
B
Canthidermis maculatus



C
Rhinecanthus aculeatus



D
Sufflamen chrysopterus



E
Rhinecanthus echarpe

Figure 8. Gill rakers of the fishes of the family Balistidae

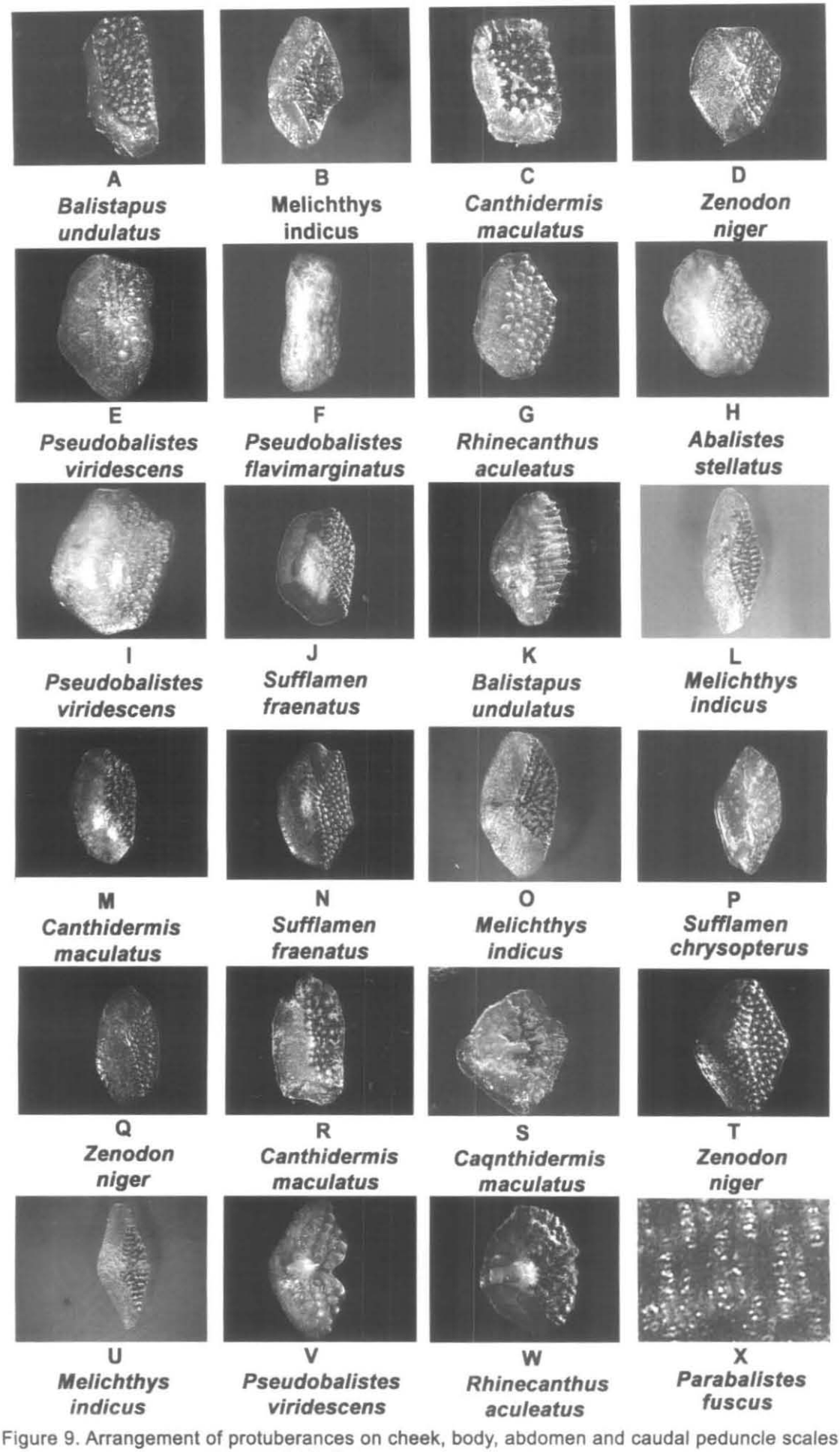
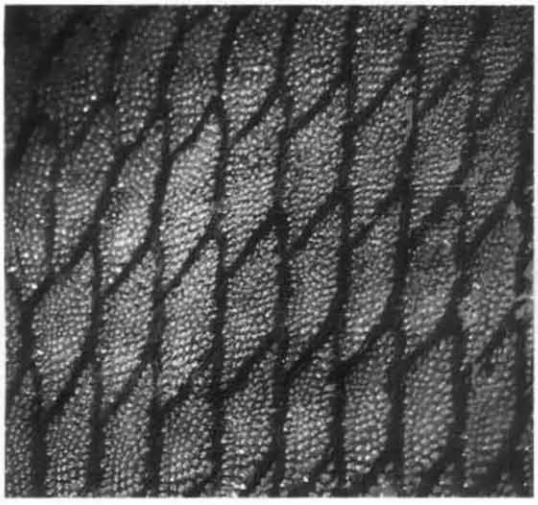
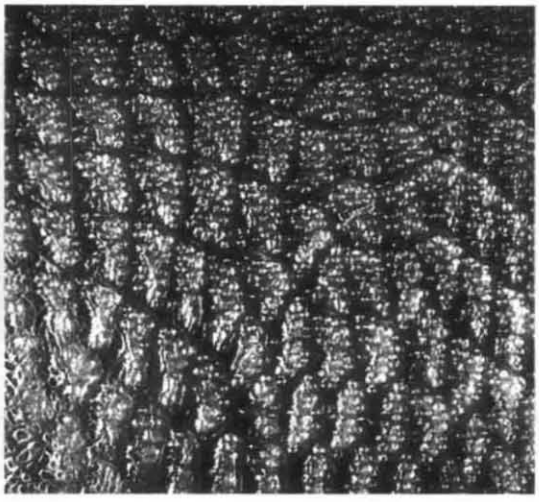


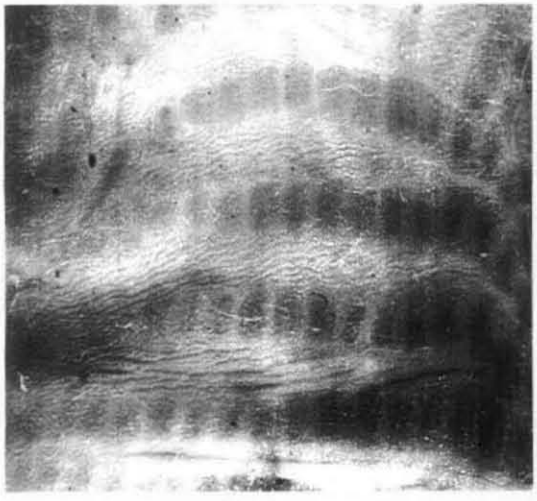
Figure 9. Arrangement of protuberances on cheek, body, abdomen and caudal peduncle scales in the fishes of the family Balistidae



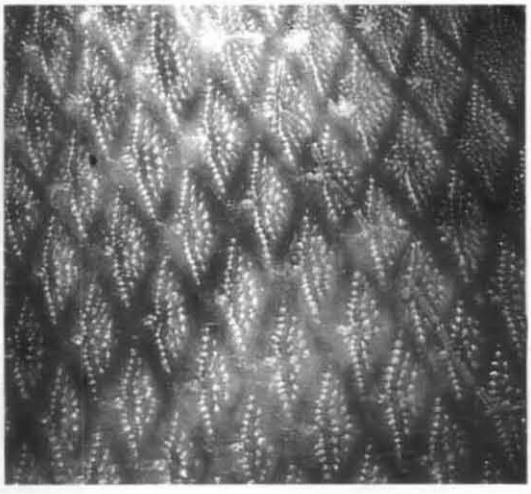
A. ***Abalistes stellatus***



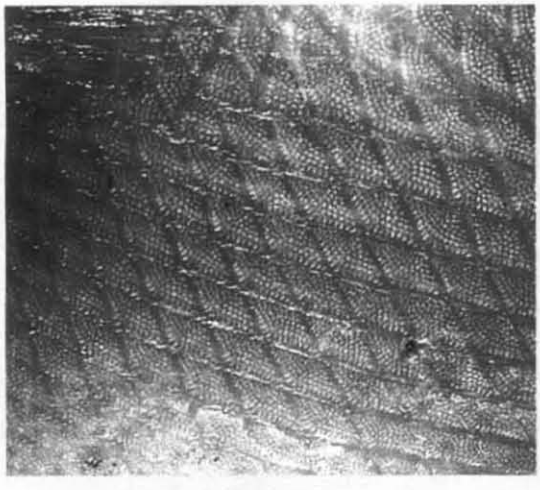
B. ***Rhinecanthus echarpe***



C. ***Parabalistes fuscus***



D. ***Abalistes stellatus***

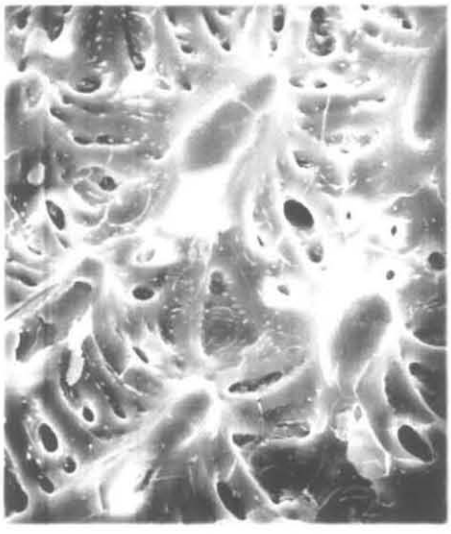


E. ***Sufflamen fraenatus***

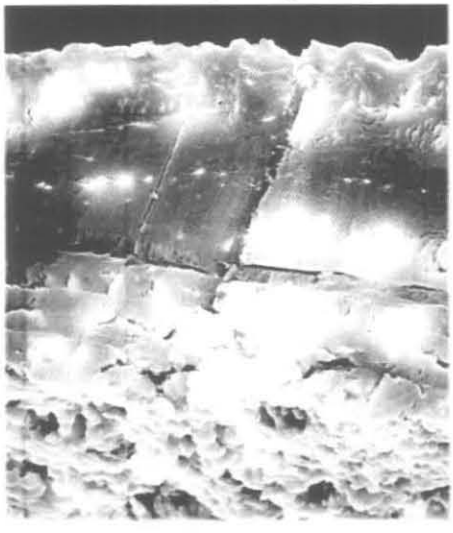
F. ***Sufflamen fraenatus***

Figure10. Arrangement of scales on cheek, body, abdomen and caudal peduncle of the fishes of the family Balistidae

A.Transverse section showing the four layers (100x)

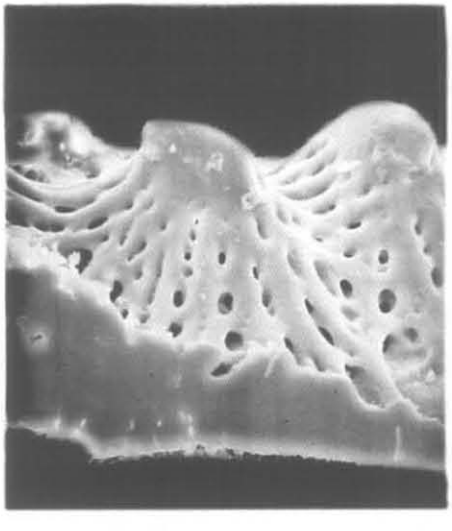


B. Glassy layer (100x)

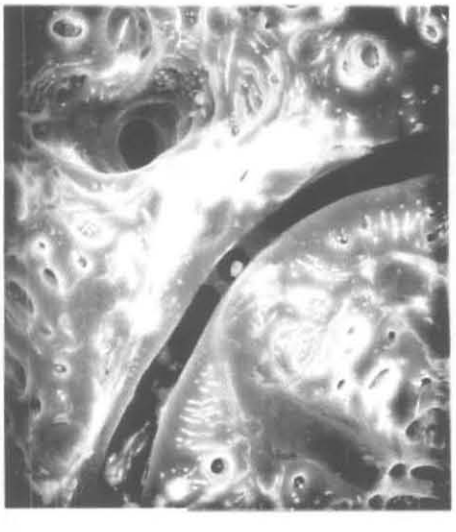


C. The network of canals (200x)

D. Thickest bottom layer (200x)



E. Posterior end of posterior margin (200x)



F. Central canal and lateral line canal (200x)

Figure 11. Ultra structure of body scale of *Abalistes stellatus*

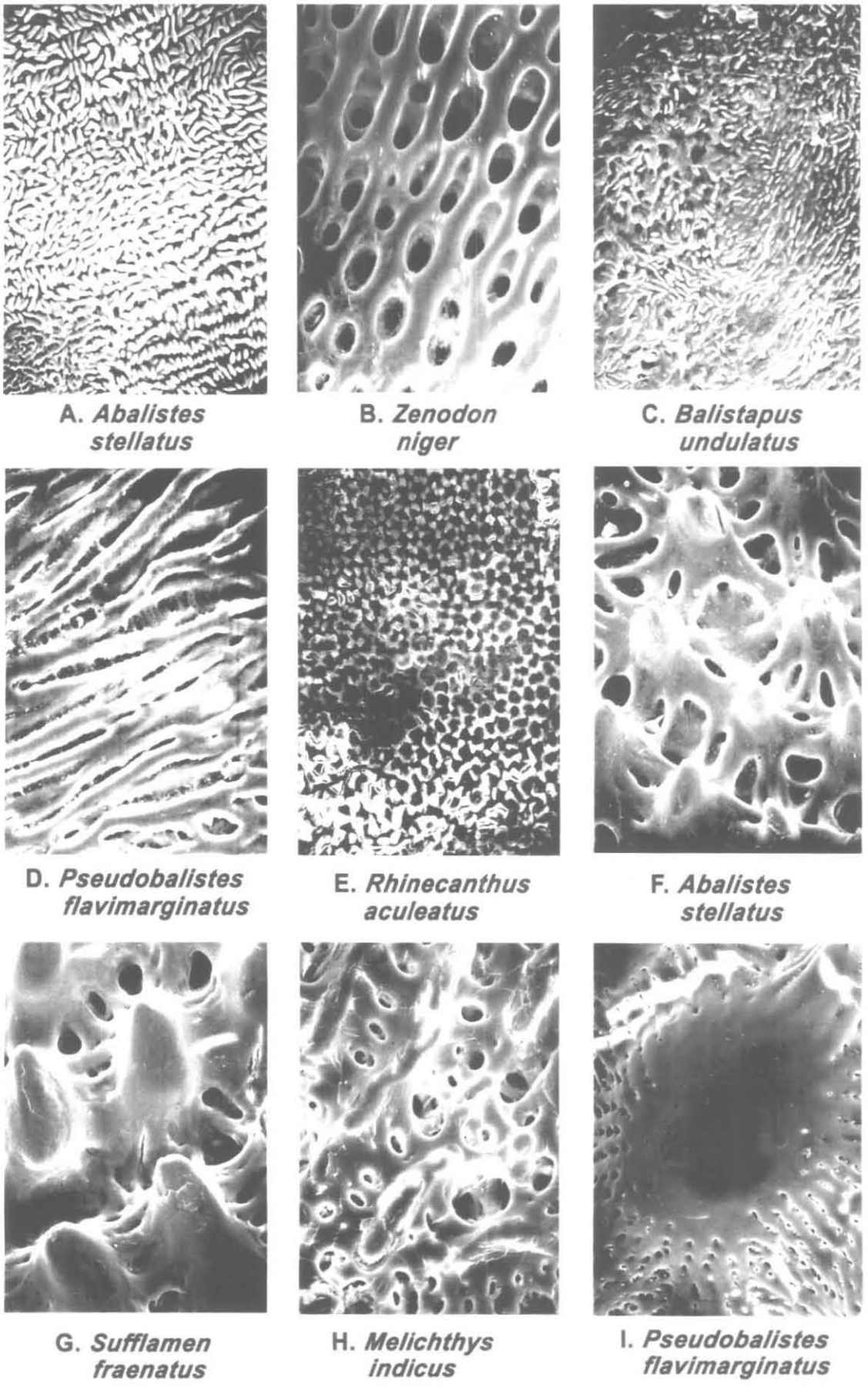


Figure 12. The ultra structure of the body scale of the fishes of the family Balistidae, A-E the anterior margin, F-I the posterior margin

2.4 Genera and species

The literature on taxonomy on Balistidae reveals that a total of 33 genera (including some subgenera) were erected from Linnaeus (1758) times till date. There have been very few taxonomic revisions of this family (Bleeker, 1866; Fraser- Brunner, 1935; Matsuura, 1980) and the authors made observation on validity or otherwise on these genera and subgenera. Eschmeyer (1998) compiled all the available information on the genera by taking into account the observations of the revisers. According to him only 12 genera are valid the details are furnished in the table 1. In the Indian seas nine genera and thirteen species of the family Balistidae were recorded which is described in the present study. They are as follows:

S. No.	Genera	Species
1.	*Balistapus* Tilesius, 1820	*1. Balistapus undulatus* (Mungo Park, 1797)
2.	*Zenodon* (Ruppell, 1835) Swainson, 1839	2. *Zenodon niger* (Ruppell, 1835)
3.	*Rhinecanthus* Swainson, 1839	3. *Rhinecanthus aculeatus* (Linnaeus, 1758) 4. *R. echarpe* (Lacepede, 1798)
4.	*Melichthys* Swainson, 1839	5. *Melichthys indicus* Randall and Klausewitz, 1973
5.	*Canthidermis* Swainson, 1839	6. *Canthidermis maculatus* (Bloch, 1786)
6.	*Parabalistes* Bleeker, 1866	7. *Parabalistes fuscus* (Bloch and Schneider, 1801)
7.	*Pseudobalistes* Bleeker, 1866	8. *Pseudobalistes viridescens* (Bloch and Schneider,1801) 9. *P. flavimarginatus* (Ruppell, 1828) 10. *P. conspicillum* (Bloch and Schneider,1801)
8.	*Sufflamen* Jordan, 1916	11. *Sufflamen fraenatus* (Latreille, 1804) 12. *S. chrysopterus* (Bloch and Schneider, 1801)
9.	*Abalistes* Jordan and Seale, 1906	13. *Abalistes stellatus* (Lacepede, 1798)

Table 1

List of Genera and Sub genera erected in the family Balistidae and observations of the revisers

S. No.	Genera	Author	Type	Observations of revisers on the validity			Compilations of Eschmeyer(1998)
				Bleeker(1866)	Fraser-Brunner(1935)	Matsuura (1980)	
1	*Balistes*	Linnaeus,1758	*Balistes vetula* Linnaeus, 1758	Valid	Valid	****	Valid
2	*Capriscus*	Klein, 1777	*Capriscus Tribus Aculeis* Klein, 1777	****	****	****	Synonym of *Balistes*
3	*Capriscus*	Rose, 1793	*Balistes pulcherrimus* Lesson,1830	****	****	****	Synonym of *Balistes*
4	*Capriscus*	Rafinesque,1810	*Capriscus porcus* Rafinesque,1810	****	Synonym of *Balistes*	****	Synonym of *Balistes*
5	*Balistapus*	Tilesius,1820	*Balistapus capistratus* Tilesius,1820	Subgenus of *Balistes*, Valid	Valid	Valid	Valid
6	*Rhinecanthus**	Swainson, 1839	*Balistes ornatissimus* Lesson, 1830	Synonym of *Balistapus*	Valid	Valid	Valid
7	*Melichthys**	Swainson, 1839	*Balistes ringens* Osbeck, 1765 (not of Linnaeus)	Valid	Valid	Valid	Valid
8	*Canthidermis**	Swainson, 1839	*Balistes oculatus* Gray,1830	Subgenus of *Balistes*, Valid	Valid	Valid	Valid
9	*Zenodon**	Swainson, 1839	*Xenodon niger* Rüppell,1836	Synonym of *Erythrodon*	****	Synonym of *Odonus*, misprint	Synonym of *Odonus*
10	*Chalisoma**	Swainson, 1839	*Balistes pulcherrimus* Lesson,1830	Synonym of *Balistes*	****	****	Synonym of *Balistes*
11	*Leiurus**	Swainson, 1839	*Leiurus macrophthalmus* Swainson,1839	Valid	Synonym of *Abalistes*, Preoccupied	*Leiurus* preoccupied	Homonym
12	*Pachynathus**	Swainson, 1839	*Pachynathus triangularis* Swainson,1839	Synonym of subgenus *Balistapus*	Synonym of *Sufflamen*	****	Synonym of *Sufflamen*
13	*Epimonus*	Rafinesque,1815	No type	****		****	****
14	*Xenodon*	Ruppell, 1836	*Xenodon niger* Rüppell,1837	Synonym of *Erythrodon*	Synonym of *Odonus*, Preocuupied	Preoccupied in reptiles	Homonym
15	*Liocornus*	Tortonese,1839	*Balistes unicornus* Basilewski,1855	****	****	****	****
16	*Odonus*	Gistel, 1848	*Xenodon niger* Rüppell,1837	****	Valid	Valid	Valid
17	*Erythrodon*	Ruppell, 1852	*Xenodon niger* Rüppell,1837	Valid	****	Synonym of *Odonus*	Synonym of *Odonus*
18	*Pyrodon*	Kaup, 1855	*Balistes niger* Rüppell,1837	Synonym of *Erythrodon*	Synonym of *Odonus*	****	Synonym of *Odonus*
19	*Xanthichthys*	Kaup,1856	*Balistes curassavicus* Gmelin,1788	Synonym of *Canthidermis*	Valid	Valid	Valid
20	*Pseudobalistes**	Bleeker, 1866	*Balistes flavimarginatus* Bleeker,1865	New genus erected by Bleeker (subgenus of *Balistes*)	Valid	Valid	Valid
21	*Parabalistes**	Bleeker, 1866	*Balistes chrysospilos* Bleeker,1853	New genus erected by Bleeker (subgenus of *Balistes*)	Synonym of *Pseudobalistes*	****	Monotypic,no comments
22	*Abalistes*	Jordan and seale, 1906	*Leiurus macrophthalmus* Swainson,1839	****	Valid	Valid	Valid, Replace ment name for *Leiurus*
23	*Sufflamen*	Jordan, 1916	*Balistes capistratus* Shaw,1804	****	Valid	Valid	Valid
24	*Verrunculus*	Jordan, 1924	*Balistes polylepis* Steindachner,1876	****	Valid	****	Synonym of *Balistes*
25	*Tobinia*	Whitely,1933	*Tobinia paragaudata* Whitley,1933	****	****	****	****
26	*Balistoides*	Fraser-Brunner,1935	*Balistes viridescens* Bloch & Schneider,1801	****	New genus erected by the Author	Valid	Valid
27	*Nematobalistes*	Fraser-Brunner,1935	*Balistes forcipatus* Gmelin,1788	****	New genus erected by the Author	****	Synonym of *Balistes*
28	*Hemibalistes**	Fraser- Brunner, 1935	*Balistes bursa* Bloch & Schneider,1801	****	New Subgenus erected by the Author	Synonym of *Sufflamen*	Synonym of *Sufflamen*
29	*Allomonacanthus*	Fraser-Brunner,1941	*Monacanthus convexirostris* Günther,1870	****	****	****	****
30	*Oncobalistes*	Fowler, 1946	*Oncobalistes erythropterus* Fowler,1946	****	****	Synonym of *Melichthys*	Synonym of *Melichthys*
31	*Tantalisor*	Whitely,1947	*Tantalisor pauciradiatus* Whitley,1947	****	****	****	****
32	*Hanomanctus*	Smith,1949	*Hanomanctus bovines* Smith, 1949	****	****	****	Synonym of *Cantherines*
33	*Xenobalistes*	Matsuura,1981	*Xenobalistes tumidipectoris* Matsuura,1981	*****	****	****	Valid

** Originally erected as subgenus*

2.5 Description of species

2.5.1 Genus *Balistapus* Tilesius, 1820

(Type species *Balistapus capistratus* Tilesius, 1820)

Diagnosis

Anterior nostril conical with pore at the tip. Groove before eye absent. Scales on cheek rhomboid, arranged in vertical rows. Body scales have retrose spines. Caudal peduncle short and deep, with two rows of antrose spines. Ventral flap absent. Caudal fin truncate.

2.5.1.1 *Balistapus undulatus* (Mungo Park, 1797)

(Figure 16)

Balistes undulates Mungo Park, 1797, p.37.
Balistes undulatus Day, 1878, p.691.
Balistapus undulatus Jones and Kumaran, 1980, p. 672, fig.572.

Material examined: 12 specimens from Lakshadweep, (8 females, 3 males, 1 indeterminate,) ranging from 41 to 277 mm TL, 11 specimens from Lakshadweep, CMFRI-LA-F. Reg. No. 154/478, ranging from 98 to 254 mm TL, one specimen from Lakshadweep, Reg. No. 565, of length of 191 mm TL.

Additional material examined: Three specimens from Tuticorin, (2 females, 1 male) of lengths 204, 240, 274 mm TL (Fig. 16.A.), one specimen from Nicobar, ZSI. Reg. No. F 6028/2, of length of 212 mm TL, Three specimens no locality mentioned, ZSI Reg. No. 8899 (Fig.16.F.), No.2737 (Fig. 16.E.), of lengths 127, 170,177 mm TL, one specimen from Andaman, ZSI Reg. No. 2256, of length of 167 mm TL, collected by Dr. F. Day (Fig. 16.D.).

Description

D. III, i, 24–26; P. i, 11–13; ventral spines 11–24; A. i, 22-23; C. ii, 10; gill rakers 30-33; number of scales from origin of second dorsal to base of anal 16–20; lateral line scales 32–36; scales round the caudal peduncle 7–11.

As percent of head: Head height 100.0–123.91 (114.79); head width 35.71–72.09 (53.93); orbit 12.94–28.57 (19.34); interorbital 21.43–26.09 (23.54); postorbital 4.35–11.76 (8.16). The regressions of different head dimensions on head are given in figure 13.

As percent of standard length: Depth 40.63–46.03 (43.74); head 34.48–43.75 (37.23); snout 21.88–29.55 (27.22); predorsal length (I) 33.71–40.63 (37.04); predorsal length (II) 61.18–69.49 (65.81); preanal length 70.00–75.74 (72.13); postdorsal length (I) 37.01–44.92 (40.75); postdorsal length (II) 2.36–6.18 (4.71); base of first dorsal 17.80–25.15 (22.80); base of second dorsal 26.67–33.53 (29.95); base of anal 20.34–25.29 (23.45); second dorsal 9.38–13.79 (11.57); anal 9.38–13.49 (11.18); pectoral 9.94–13.53 (11.66); caudal peduncle 9.38–12.71 (11.54). The regressions of different body dimensions on standard length are given in figure 14 & 15.

Body deep, rhomboid. Head profile, straight. Lips broad thick, continuous at the corner. Interorbital straight. First spine, stout, laterally elliptical, third spine ¼ the length of first spine. Nasal apertures placed in two separate shallow depressions (Fig.17. A). The first teeth of upper and lower jaw conical with pointed tips diverging outside, other three teeth rectangular with the upper side conical on one side (Fig.17. B).

There are four to five large scales, rectangular with edges round, above pectoral base, arranged in an rectangular region, smaller scales, few, arranged at its periphery. The gill rakers hyaline with blunt edges and hairy bristle like projection (Fig.17.C). The second dorsal and anal fin profile convex, transparent. Pectoral round.

Scales on cheek are rhomboid, having 3-8 vertical rows of round protuberances (Fig. 17. D & Fig. 18.A). Body scale, with 2 - 4 vertical rows of retrose spines (Fig. 17.E

& Fig.18.B). The ultra structure of the anterior portion of the body scale has pits and ridges (Fig.18. E –G) and the posterior portion has retrose spines (Fig.18. H - J). Scales on abdomen are rhomboidal and rectangular, with 3-4 oblique rows of ridges (Fig.17.F & Fig.18.C). Caudal peduncle has two types of scales 1) Diamond shaped scales with antrose spine at the anterior middle and 5-8 horizontal rows of ridges. 2) Diamond shaped scales with ridges and retrose spines arranged in 2 –4 vertical rows (Fig.17.G & Fig. 18.D).

Ventral spine 11 – 24 pointed. Pelvic spine, short, blunt and spinules blunt.

Colour

Fish green, with 13–14 orange, curved oblique bands, originating just anterior to eye, below first dorsal, space between first dorsal and second dorsal. The bands end at anus, base of anal and at base of caudal. Inter orbital has 7–8 orange transverse bands. The anterior part of cheek has orange dots (male) or bands (female). Lower lip is orange upper lip black. Just above upper lip is an orange band followed by blue and orange band. Just below lower lip is blue band followed by a orange and blue band, which merge at the corner of the mouth forming orange, blue, orange and blue band which extend ventrally towards anus. The first dorsal dull yellow, with triangular black blotch at the tip. Second dorsal, anal and pectoral fins have orange ray, base of rays blue and membrane transparent. Caudal orange.

Colour of the preserved specimens: The formalin-preserved specimens dark brown. Just above upper lip are present two yellow bands and just below lower lip is a yellow band, which merges at corner of the mouth and form two yellow bands, which extend ventrally towards anus. A triangular black blotch at the tip of first dorsal, membrane transparent. The second dorsal, anal, and pectoral fin have yellow rays, membrane transparent. Caudal yellow. The alcohol preserved specimens also have a similar colour.

Distribution

Sumatra (Mungo Park, 1797); Coramandel (India) (Bloch and Schneider, 1801); Coraline Islands (Quoy and Gaimard, 1824); Tahiti (Lay and Bennett, 1839); Solor, Banda Neira (Ceram); Coromandelia (India), Ambonia, New Guinea, Makassar, Bulukomba, Badjoa, Manado, Kema (Celebes), Trussan, Padang, Priaman, (Sumatra), Japan (Bleeker, 1852, 1853, 1857, 1859, 1860); Von (Java) (Kner, 1865); Red sea, Zanzibar, Moluccas, Sumatra, Ambonia, Ceram, Zebu, China, Japan, Louisiade Archipelago (Gunther, 1870); Andaman (Day, 1878); Papeete, (Tahiti), Fate (New Hebrides), Shortland Island (Solomons Island), Raiatea (Society Island) (Seale, 1906); Bacon (Philippines) (Everman and Seale, 1907); Muaras – Riff (Celebes sea) Sanguisiapo, Tawi-Tawi – Island (Sulu Archipelago), Lirung (Salibabu Island), Salomakiee Island, Waruh-Bucht (Ceram) Saleyer Reef, Binongka Island, Nalahia (Nusa Island), Feer (Hoch-Kei Reef), Sailus Besar (Paternoster Island) (Weber, 1913); Zamboanga (Philippines) (Fowler and Bean, 1922); St. Mathias Island (Ducker and Mohr, 1929); Daikuma (Japan) (Schmidt, 1930); Moorea, Suva (Fiji), Malo Island, Hog harbour, Esptritu Santo Island, Wala Island, (New Hebrides) Ugi Island, Tenibuli Ysabel Island (Solomon Islands) (Herre, 1936); Thornton Island, Tai-O-Hae Bay, Comptroller Bay, Nukuhiva (French Polynesia) (Fowler, 1938); Rennell Island (Solomon Island) (Rofen, 1958); Bikini Atoll, Eniwetok Atoll, Ronge lap Atoll, Guam, (Marshall Island) (Schultz, 1966);. Okinawa Island, Ryukyu Island, Ishigaki Island (Japan) (Matsuura, 1980); Maldives (Jones *et al*., 1981); Sesoko Island (Japan) (Kuwamura, 1991); Thailand (Nateewathana *et al*., 1993); Hsiaoliuchiu (Taiwan) (Shao *et al*., 1994) (Fig. 19. A & B).

Remarks

1) This species is rare in catches along the east coast of India and only three specimens could be collected.
2) The specimens of 20 mm length are metallic brown dorsally and silvery ventrally (Fig.16.B). In those of 40 mm length, the body is green with orange undulating lines laterally (Fig.16.C).

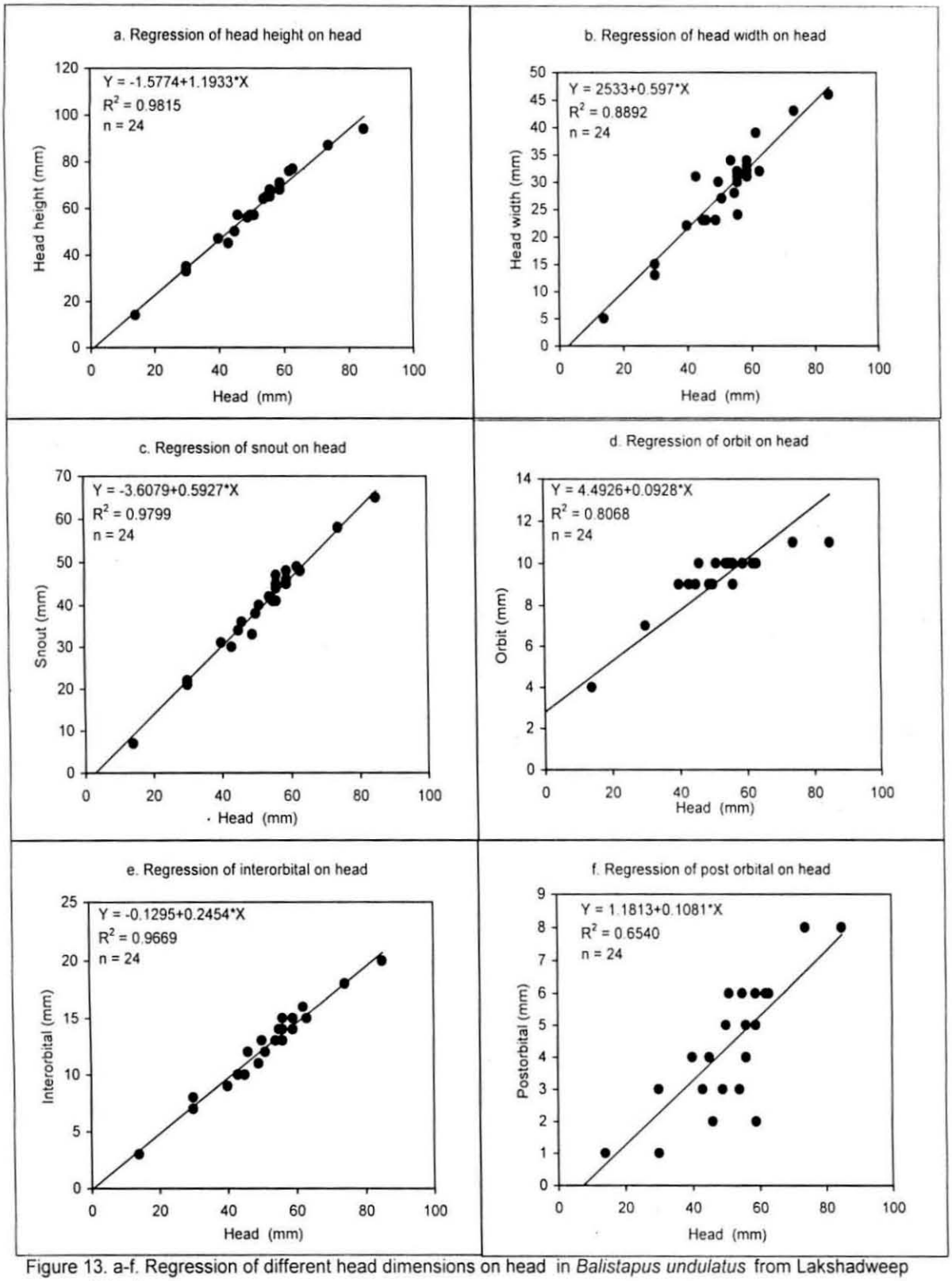


Figure 13. a-f. Regression of different head dimensions on head in *Balistapus undulatus* from Lakshadweep Islands.

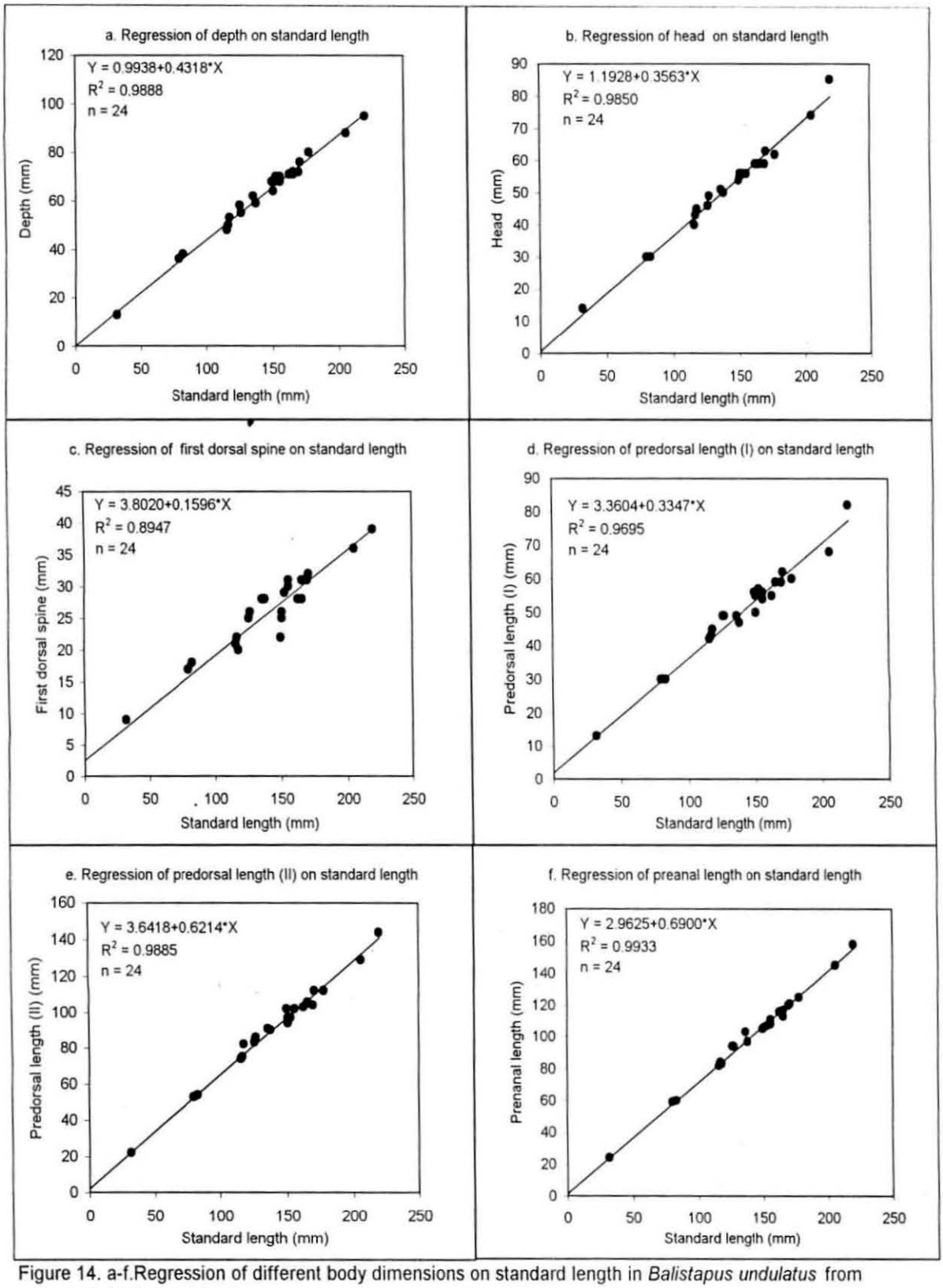


Figure 14. a-f.Regression of different body dimensions on standard length in *Balistapus undulatus* from Lakshadweep Islands.

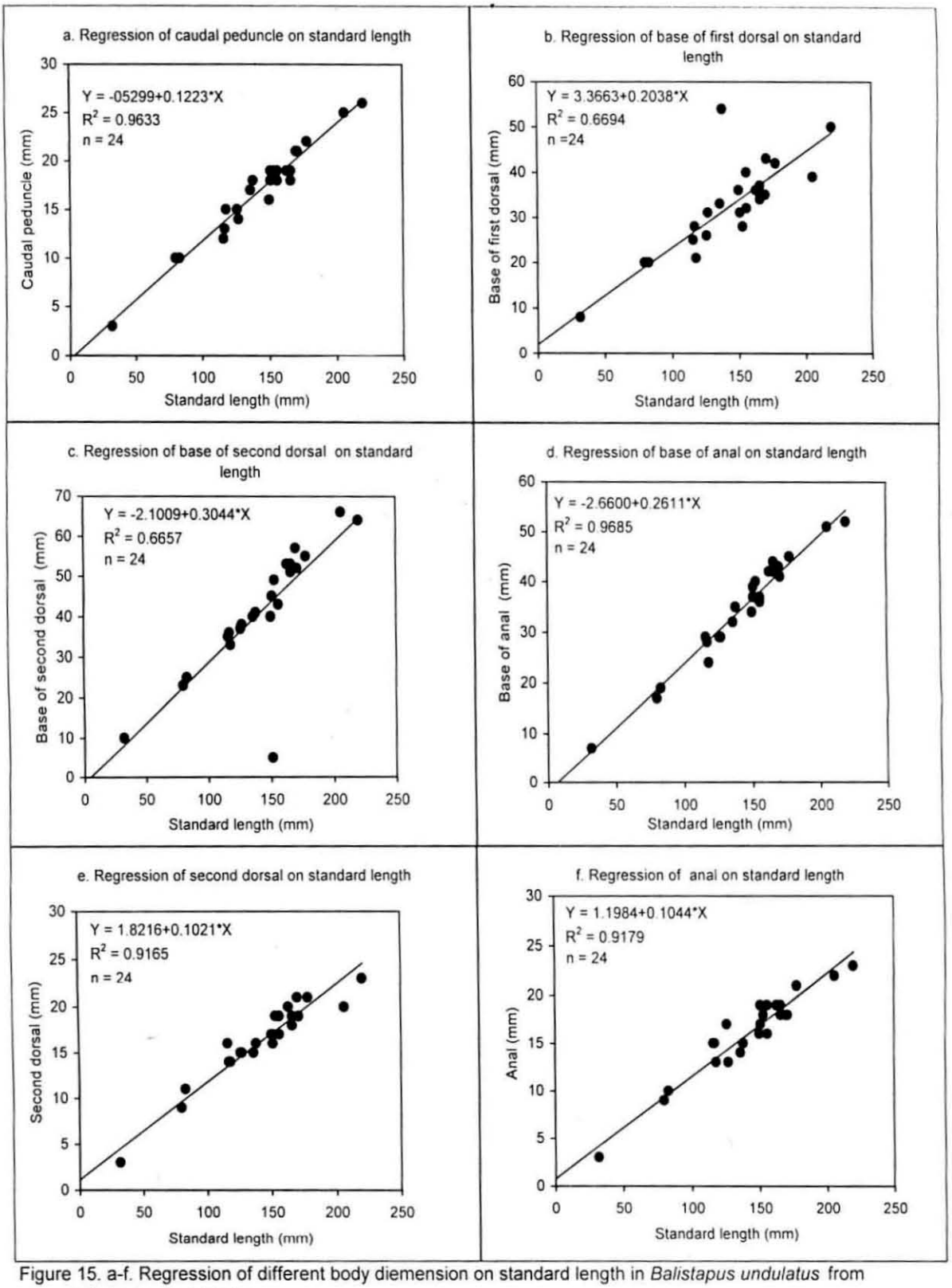


Figure 15. a-f. Regression of different body diemension on standard length in *Balistapus undulatus* from Lakshadweep Islands.

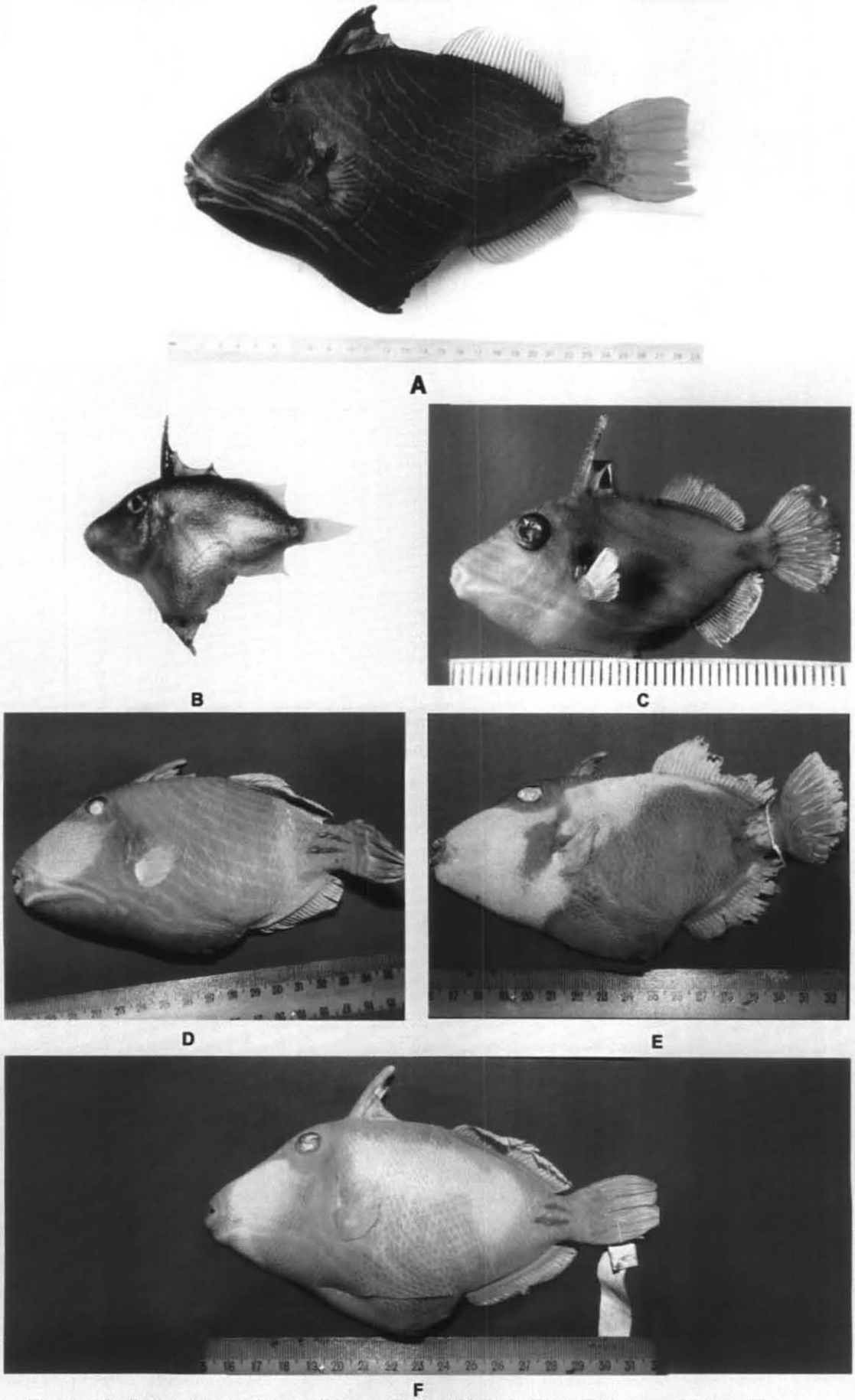


Figure 16. *Balistapus undulatus* (Mungo Park, 1797): A. From Tuticorin, 274mm TL, B. From Kavartti 20 mm TL, C. From Kavartti 41 mm TL, D. From Andaman ZSI Reg. No. 2256, 167 mm TL, collected by Dr. F. Day, E. ZSI Reg. No. 2737, 177mm TL, F. ZSI Reg. No. 8899, 170 mm TL.

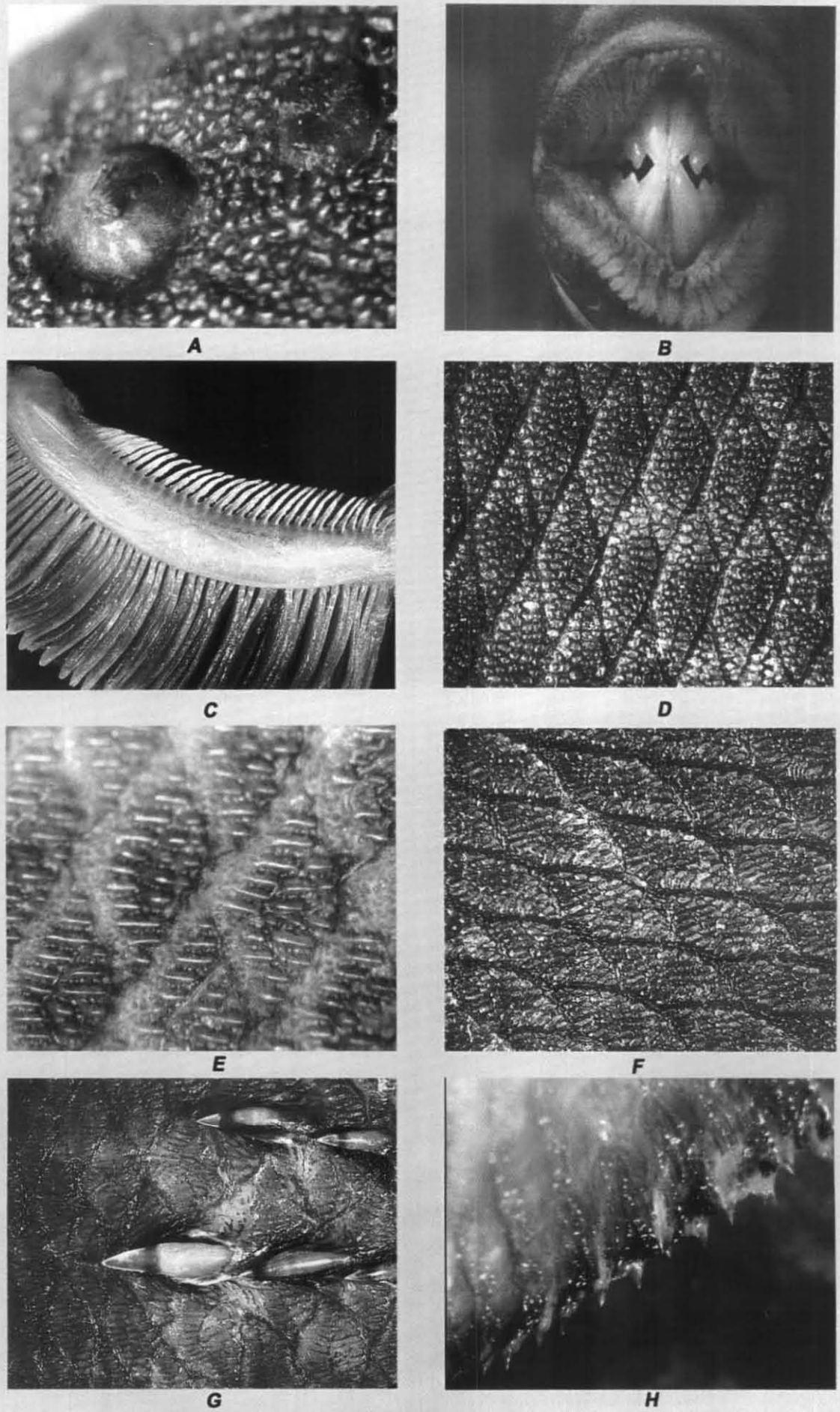


Figure 17. *Balistapus undulatus* (Mungo park, 1797), A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

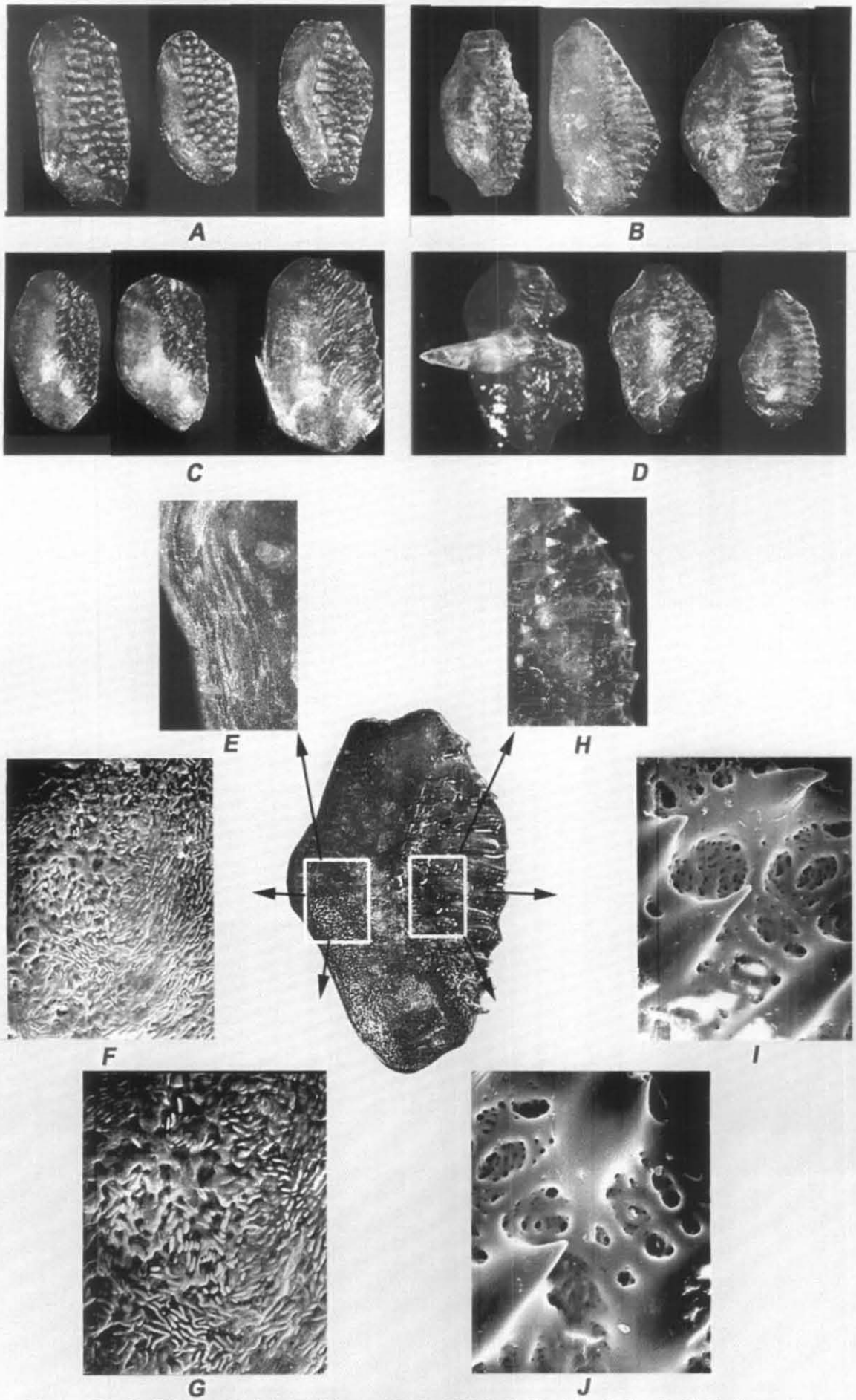
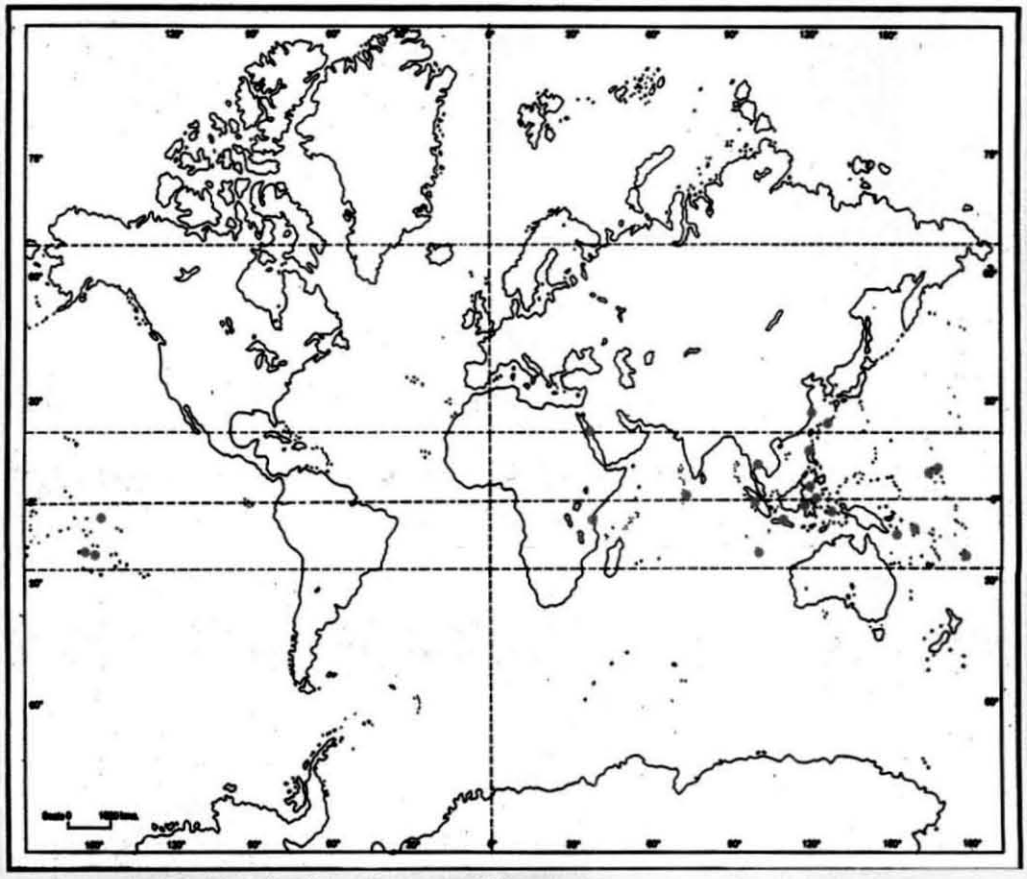
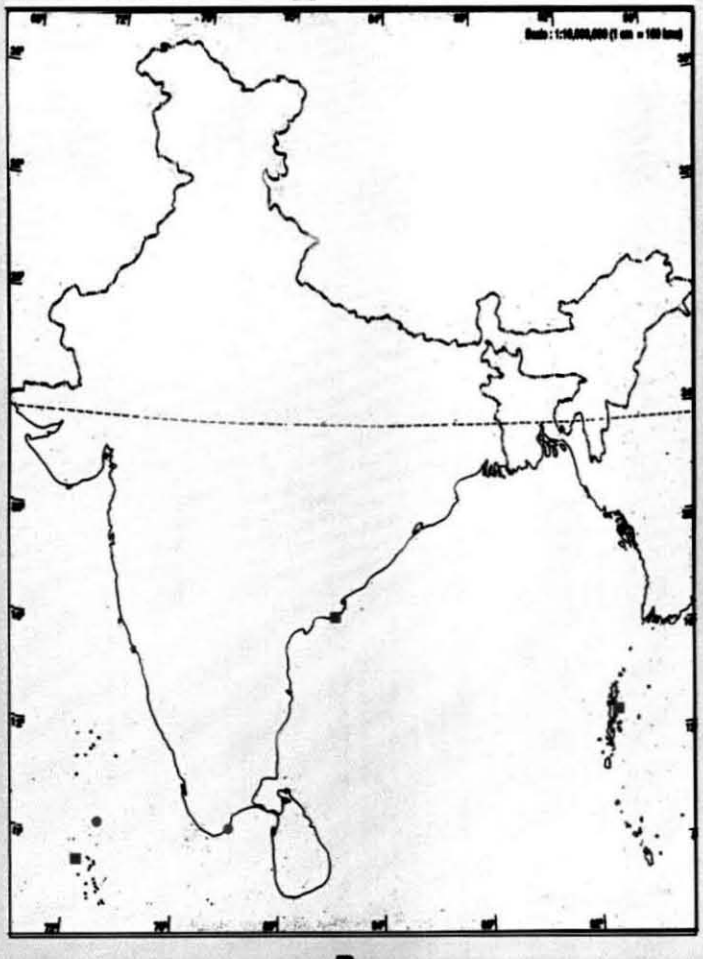


Figure 18. *Balistapus undulatus* (Mungo Park, 1797): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.



A



B

Figure 19. *Balistapus undulatus* (Mungo Park, 1797), A. Distribution in world, B. Distribution in India, ■ on Indian map indicates collections made by previous authors, ● on Indian map indicates the places from where specimens were collected

2.5.2. Genus *Zenodon* (Ruppell, 1835) Swainson, 1839

(Type species *Xenodon niger*, Ruppell, 1835)

Diagnosis

Nostrils short tubes. Groove before eye present. Scales on cheek rhomboid with round protuberances and ridges. Body scales and caudal peduncle scales have round protuberances and ridges and a large spherical protuberance at the anterior middle of these scales. Caudal peduncle longer than deep, laterally elliptical. Ventral flap present. Caudal lunate with lobes produced.

The genus *Xenodon* was erected by Ruppell (1835) with *Xenodon niger* Ruppell (1835) as the type species. Swainson (1839) gave the name *Zenodon* to this genus and ascribed it to Ruppell (1835); he (Swainson, 1839) apparently treated this as the subgenus of *Capriscus*. In 1848 Gistel erected another genus: *Odonus* for *Xenodon niger* Ruppell, 1835. Ruppell 1852 gave the genus name *Erythrodon* to his *Xenodon* (1835) with the remark that the genus name *Xenodon* was already available in Amphibia and therefore preoccupied. Kaup (1855) described the genus *Pyrodon* for *Xenodon niger* Ruppell, 1835 and ascribed the authorship to Ruppell. He also treated *Zenodon niger* Swainson, 1839 as synonym of this species. Jordan (1917) made valuable observations on the above genus names, which are presented in the table 2.

Herre (1924) observed that

> "The genus was first recognised in 1835 by Ruppell, who called it *Xenodon*, a name preoccupied in reptiles. Swainson's misprint of it in 1839 as *Zenodon* cannot be accepted as a valid substitute, while Ruppell's appropriate name of *Erythrodon*, proposed in 1852, is preceded by *Odonus*".

Subsequent authors (Fraser-Brunner, 1935; Matsuura, 1980 and Smith and Heemstra, 1980) treated the genus *Odonus* Gistel, 1848 as valid for *Xenodon niger* Ruppell, 1835.

Table 2 Observations made by Jordan (1917)

Genus	Author and Year	Remarks
Zenodon	(Ruppell, 1835) Swainson, 1839	Orthotype *Balistes niger* Lac. This name *Zenodon* being ascribed to Ruppell is probably a careless misprint of *Xenodon* Ruppell. Preoccupied in reptiles by *Xenodon* Boie, 1827. The name is spelled *Zenodon* on page 194 also. *Zenodon* is, however, accepted by Fowler (1904). If adopted, it replaces *Odonus* Gistel (1848), *Erythrodon* Ruppell (1852) and *Pyrodon* Kaup (1855)-all substitutes offered for *Xenodon*
Odonus	Gistel, 1848	Type (*Balistes niger* Lac.) A substitute for *Xenodon* Ruppell, Preoccupied. *Odonus* is prior to *Erythrodon* Ruppell, 1852, and to *Pyrodon* Kaup. If *Zenodon* Sw. (1839) is regarded as eligible, not as a mere misprint, it will be preferred to *Odonus*.
Erythrodon	Ruppell, 1852	Orthotype *Balistes niger* Lac. *Balistes Erythrodon* Gthr. Substitute for *Xenodon* Ruppell, 1835, preoccupied, but the name *Odonus* Gistel (1848) has priority and *Zenodon* Sw. (1839) is still older, if available.
Pyrodon	Kaup, 1855	Orthotype *Balistes niger* Lac. Name a substitute for *Xenodon*, preoccupied. Later than *Zenodon* Sw., *Odonus* Gistel and *Erythrodon* Ruppell, substitutes for *Xenodon*

From the above, the following conclusions can be drawn,

1) The genus *Xenodon* Ruppell, 1835 is preoccupied and therefore requires to be replaced by another name.

2) Swainson's genus name *Zenodon*, 1839 is the replacement for *Xenodon*, though the author did not specifically state so. Apparently Swainson emended *Xenodon* to *Zenodon* as he has ascribed the authorship to Ruppell (1835). The belief of the latter authors that the name *Zenodon* is misprint of *Xenodon* is not valid because Swainson was consistent in using the name *Zenodon*, in different places in his work (1839).

3) Ruppell, 1852 apparently was unaware of the publication of Swainson, 1839 and Gistel, 1848. Kaup, 1855 also apparently was unaware of the name *Xenodon* being preoccupied in Amphibia as he ascribed the authorship of his genus *Pyrodon* to Ruppell, an action similar to that of Swainson.

4) Jordan *(Vide Supra)* indeed believed *Zenodon* Swainson to be a replacement name of *Xenodon*, Ruppell though he also called it as a "careless misprint of *Xenodon* Ruppell, 1835". Fowler, 1904 accepted the name *Zenodon*.

5) The genus name *Zenodon* fulfils the requirement of availability and therefore is valid.

6) It is therefore clear that the genus name *Zenodon* Swainson is valid and needs to be resurrected. It is also clear that all the workers after Swainson (1839) simply believed that *Zenodon* to be a misprint of *Xenodon* and dismissed it as invalid, partly this happened because Swainson ascribed the genus *Zenodon* to Ruppell. For this reason this genus can be cited as *Zenodon* (Ruppell, 1835) Swainson, 1839. Obviously the genera *Odonus*, *Erythrodon* and *Pyrodon* fall as junior synonyms of *Zenodon*.

2.5.2.1. *Zenodon niger* (Ruppell, 1835)

(Figure 23)

Xenodon niger Ruppell, 1835, p.53, *pl.* 14, fig. 3.
Balistes erythrodon Day, 1878, Part IV, p.692.
Odonus niger Jones and Kumaran, 1980, p. 664, fig.565.

Material examined: 54 specimens from Colachel, (31 females, 23 males) ranging from 147 to 346 mm TL, 7 specimens from Vizhinjam, (3 females, 4 males) ranging from 209 to 300 mm TL, 32 specimens from Vizhinjam, (indeterminate) ranging from 100 to 128 mm TL.

Additional material examined: Four specimens from Tuticorin, (2 females, 2 males) of lengths 217,275,299,304 mm TL, 23 specimens from Minicoy, (3 females, 20 males) ranging from 190 to 273 mm TL, 9 specimens from Chennai, (indeterminates) ranging from 102 to 118 mm TL, one specimen from Mumbai, (female) of length of 158 mm TL, three specimens from Vizhinjam, CMFRI - F. Reg. No. 154/440, of lengths 114,159,162 mm TL (Fig. 23. C), one specimen from Trivandrum, ZSI. Reg. No. F 2611/2, 130 mm TL (Fig.23. D), one specimen from Madras, ZSI. Reg. No. 8063, of length of 366 mm TL, collected by Dr. F. Day, (Fig.23. E), one specimen from Andaman, ZSI. Reg. No. 7250, TL 164 mm (Fig.23. F).

Description

D. III, i, 31–36; P. i, 10–14; ventral spines 9–23; A. i, 26-30; C ii, 10; gill rakers 30-33, number of scales from origin of second dorsal to base of anal 10–14; lateral line scales 21-32 + 13-18; scales round the caudal peduncle 9–12.

As percent of head: Head height 109.09–138.71 (122.14); head width 34.29–58.13 (45.99); orbit 13.70–24.39 (18.91); interorbital 22.22–35.14 (29.01); postorbital 3.03–17.78 (7.80). The regressions of different head dimensions on head are given in figure 20.

As percent of standard length: Depth 39.02–47.56 (43.27); head 31.82–36.84 (34.29); predorsal length (I) 25.86–35.71 (32.34); predorsal length (II) 48.48–63.41 (57.34); preanal length 56.88–61.26 (60.89); postdorsal length (I) 40.74–67.10 (47.19); postdorsal length (II) 3.37–8.0 (6.31); base of first dorsal 15.24–27.27 (20.52); base of second dorsal 29.21–45.90 (36.77); base of anal 28.94–39.33 (33.25); second dorsal 17.05–29.51 (24.72); anal 17.39–25.66 (21.90); pectoral 8.89–11.84 (10.33); caudal peduncle 4.17–8.85 (6.68). The regressions of different body dimensions on standard length are given in figure 21 & 22.

Body rhomboid. Head profile straight, with a jetting chin. Mouth superior, lips thin and narrow. Interorbital convex. Groove longer than orbit, deep at the centre, shallow at anterior, broad towards posterior, directed downwards. First dorsal spine, short, stout,

blunt, anterior margin broad, with small protuberance and large blunt protuberances at the tip. Third spine ¼ the length of first spine. Nostrils placed in two separate depressions (Fig.24. A). The first tooth on the upper jaw rectangular and the second one caniniform and rest rectangular. The first tooth of the lower jaw is nearly concave on the upper side, with one side longer than the other (Fig. 24.B).

There are 3-5 scales in a triangular region above pectoral. Gill opening vertical. Gill rakers, thin, with pointed tip (Fig. 24.C). The anterior most rays in the second dorsal and anal are longer giving the appearance of a lobe, at the anterior side. The fins are thick, having serrated edge.

Scales on cheek have first row of ridges and followed by 4-8 rows of round protuberances (Fig. 24.D & Fig. 25.A). Body scales and scales on caudal peduncle have a large spherical protuberance and first row of ridges, followed by 5-9 vertical rows of round protuberances (Fig. 24. E & G & Fig. 25. B & D). The ultra structure of the anterior margin of the body scale has round pits (Fig. 25.E-G) and the posterior margin has round protuberances with pointed tip (Fig. 25.H-J). scales on abdomen rhomboid arranged in oblique rows with first row of ridges and followed by round protuberances arranged in 4-6 oblique rows (Fig. 24.F & Fig. 25.C).

Ventral spines arranged in two rows between the rudimentary pelvic spine and anus. The spines are pointed, in adult and bifid in juveniles (Fig. 24.H). Pelvic spine is movable, with many spinules.

Colour

Fishes above 100 mm length: The body and fins violet. Cheek with two bands one of which dark blue and other light blue, starting from the edge of the mouth and extending till the gill opening. The second dorsal, anal and caudal fins are dark blue.

Fishes below 100 mm length: Body blue, cheek with three bands which extend between mouth and gill opening; the upper and lower bands is light blue and middle band

black. One band connecting the tip of snout to eye. The caudal, second dorsal and anal edged white.

Colour in the preserved specimens: The formalin preserved specimens are dark brown with a black band on cheek starting from the edge of the mouth and ending at branchial opening. Similar colour pattern are observed in alcohol preserved specimens.

Distribution

Red Sea (Ruppell, 1835), Padang, Priaman (Sumatra), New Guinea, Makassar, (Celebes), Manado (Celebes) (Bleeker, 1852, 1859, 1860), Zanzibar, Mauritius, Ceram (Gunther, 1870), Mangalore, India (Day, 1878), Padang (Sumatra) (Fowler, 1904), Banda (Max Weber, 1913), Luzon, Sitankal, of Sulu province (Herre, 1924), Society islands; Christmas and Fanning Islands (Fowler, 1928), Yaeyama (Miyako) Island (Schmidt, 1930), Vizhinjam (Radhakrishnan, 1974), Okinawa Island, Ryukyu Island, Ishigaki Island, (Japan) (Matsuura, 1980), Maldives (Jones *et al.*, 1981), Vizhinjam Kerala, India (Talwar and Kacker, 1984), Sesoko Island (Japan) (Kuwamura, 1991), Thailand (Nateewathan, 1993), Wadge bank off the south west coast of India (Kunjupal, 1994), Shanhai, (Taiwan) (Shao *et al.*, 1994), Gulf of Oman and Arabian Sea coast of Oman (Al-Abdessalam, 1996), Cocos (Keeling) Islands and Christmas Island (Allen, 1996). (Fig. 26.A & B).

Remarks: Fishes above 190 mm exhibit sexual dimorphism. In males the lobes of lunate caudal fin are long and blunt. In females the lobes are short and pointed (Fig. 23. B).

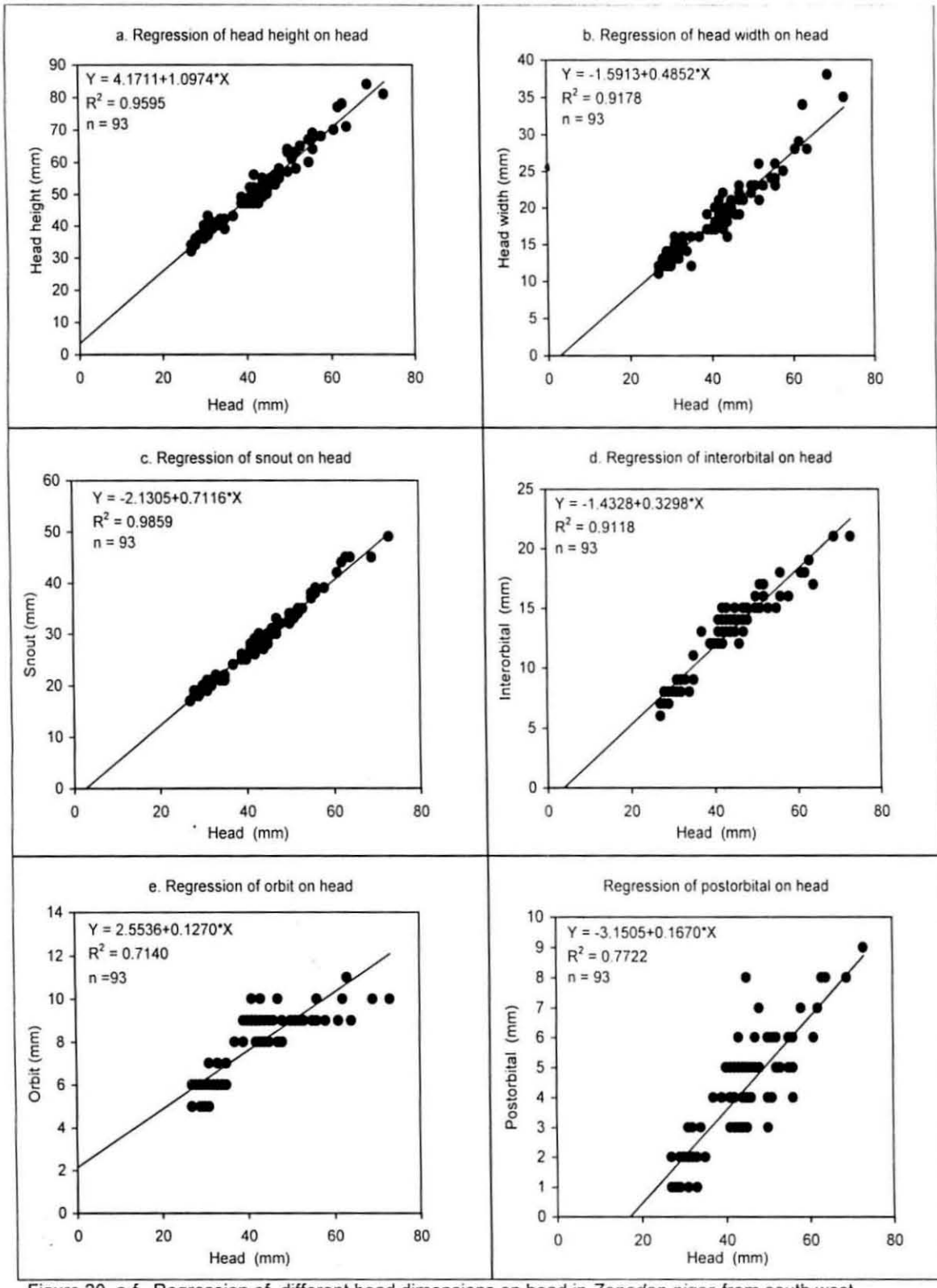


Figure 20. a-f. Regression of different head dimensions on head in *Zenodon niger* from south west coast of India.

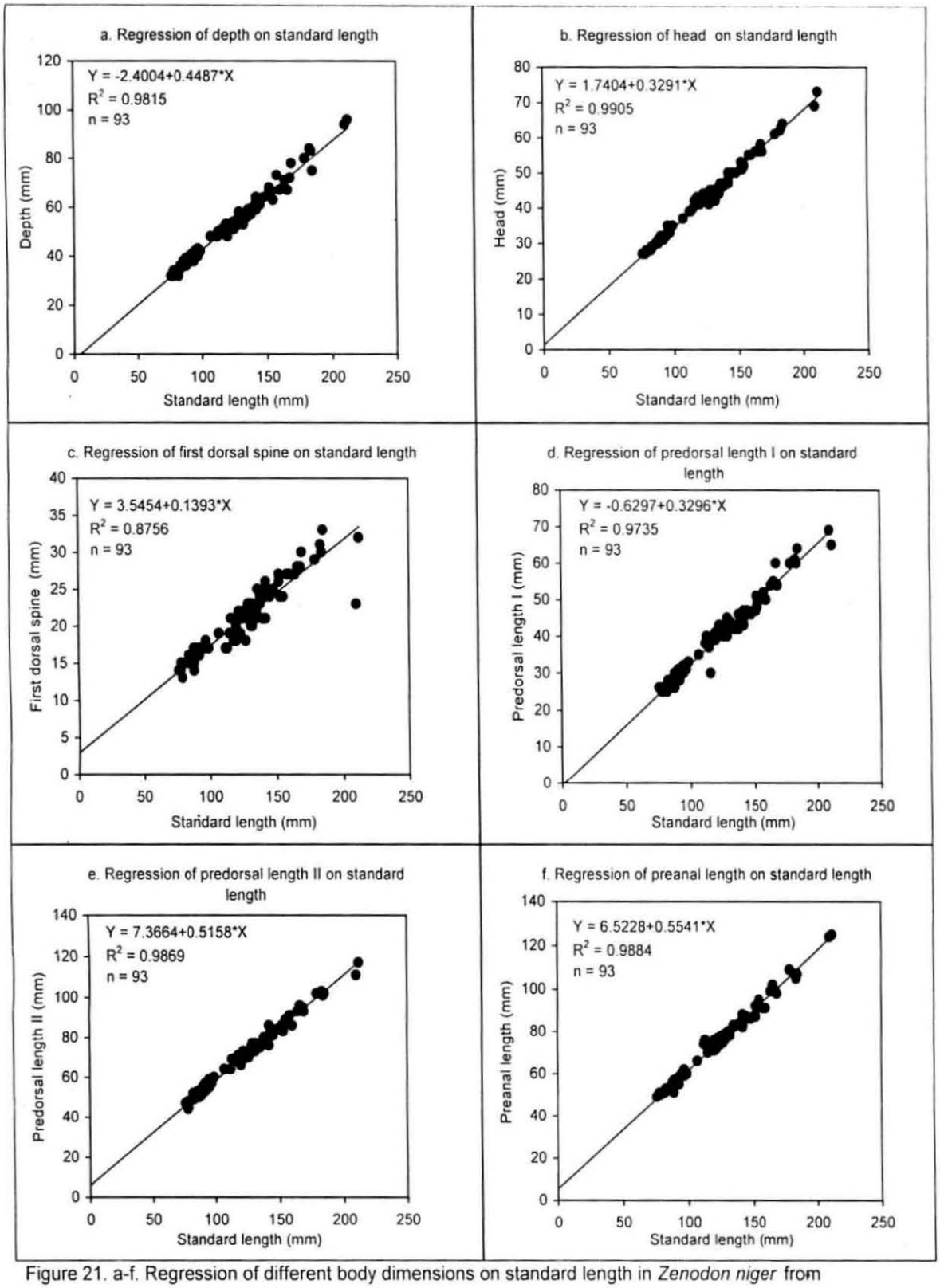


Figure 21. a-f. Regression of different body dimensions on standard length in *Zenodon niger* from south west coast of India

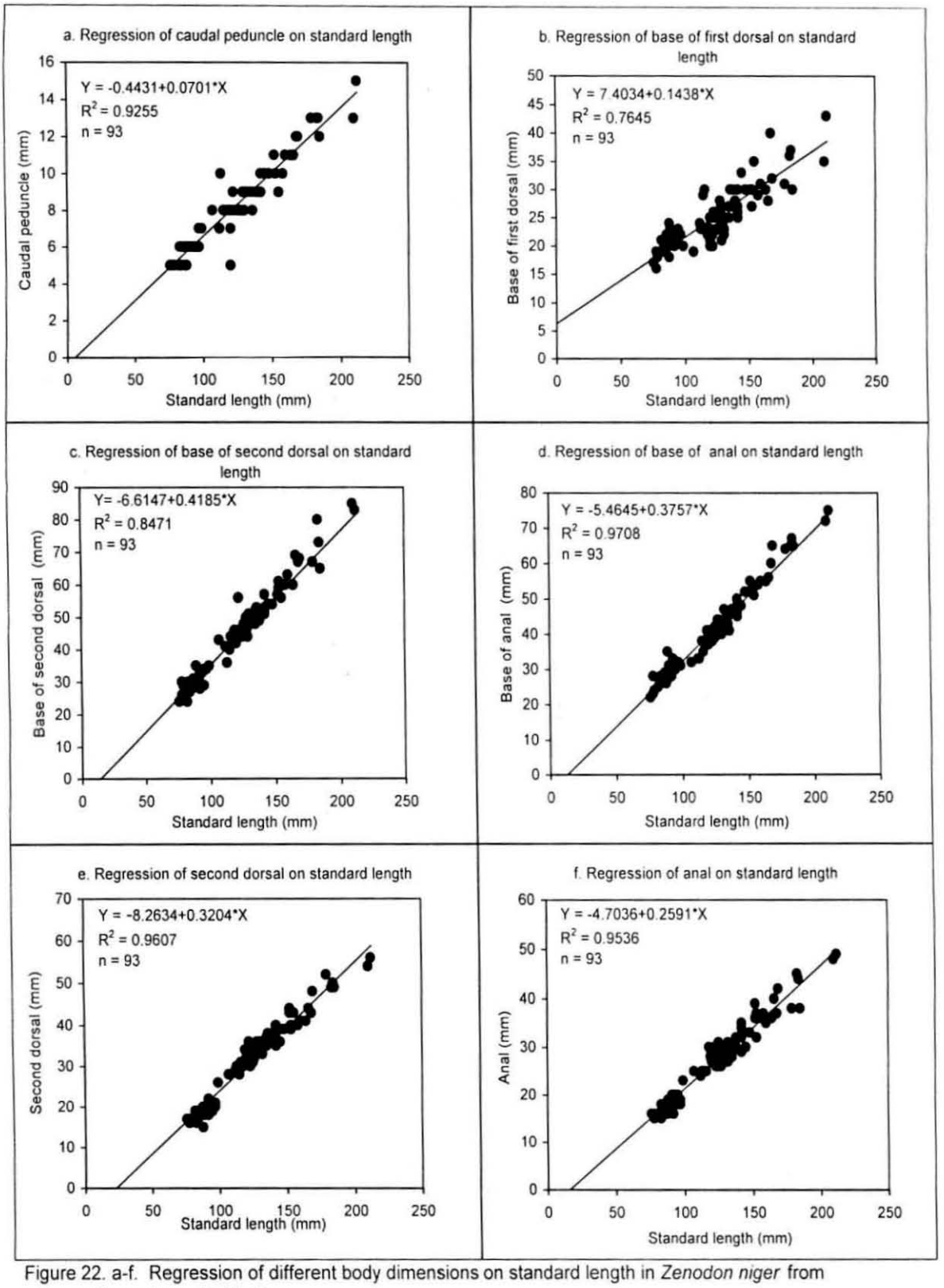
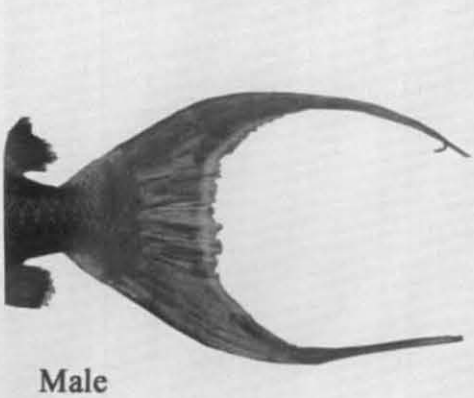
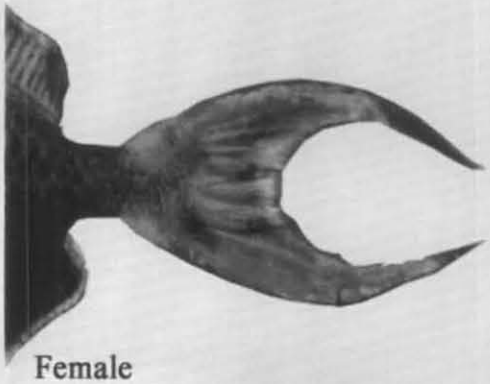


Figure 22. a-f. Regression of different body dimensions on standard length in *Zenodon niger* from south west coast of India

A

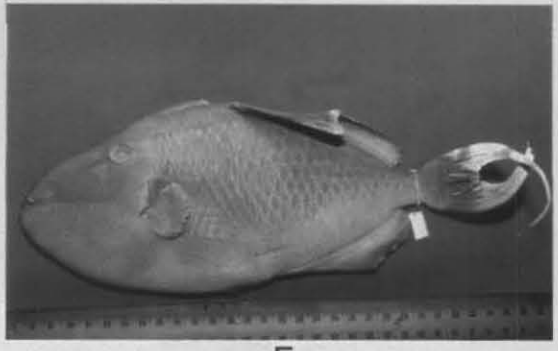




B

C

D



E

F

Figure 23. *Zenodon niger* (Ruppell, 1835): A. From Colachel 265 mm TL, B. Caudal fin of male and female, C. From Vizihinjam CMFRI-F. 154/440, 162 mm TL, D. From Trivandrum ZSI Reg. No.F2611/2, 130 mm TL, E. From Madras ZSI. Reg. No. 8063, 366 mm TL, F. From Andaman ZSI Reg. No. 7250, 164 mm TL.

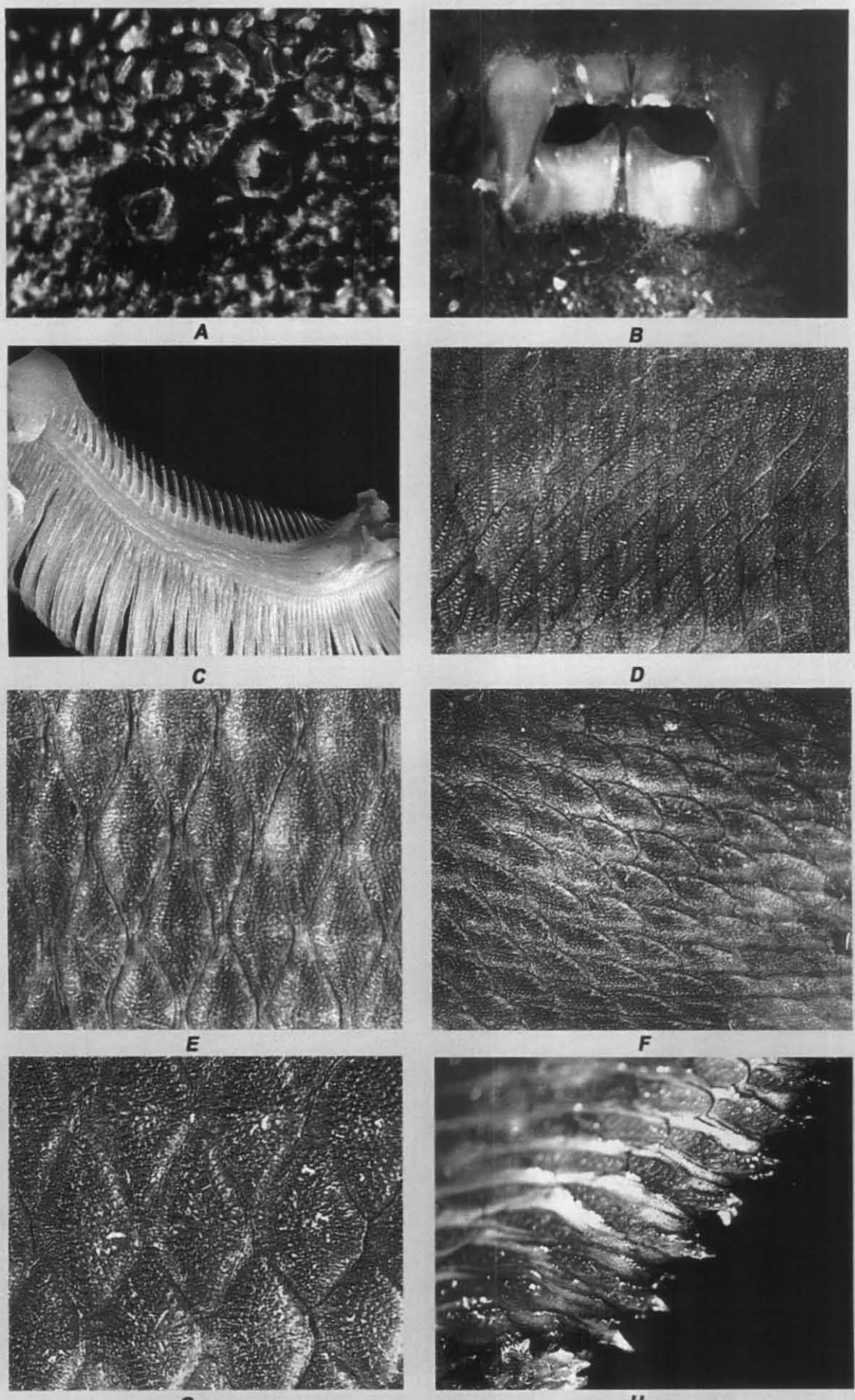


Figure 24. *Zenodon niger* (Ruppell,1835): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

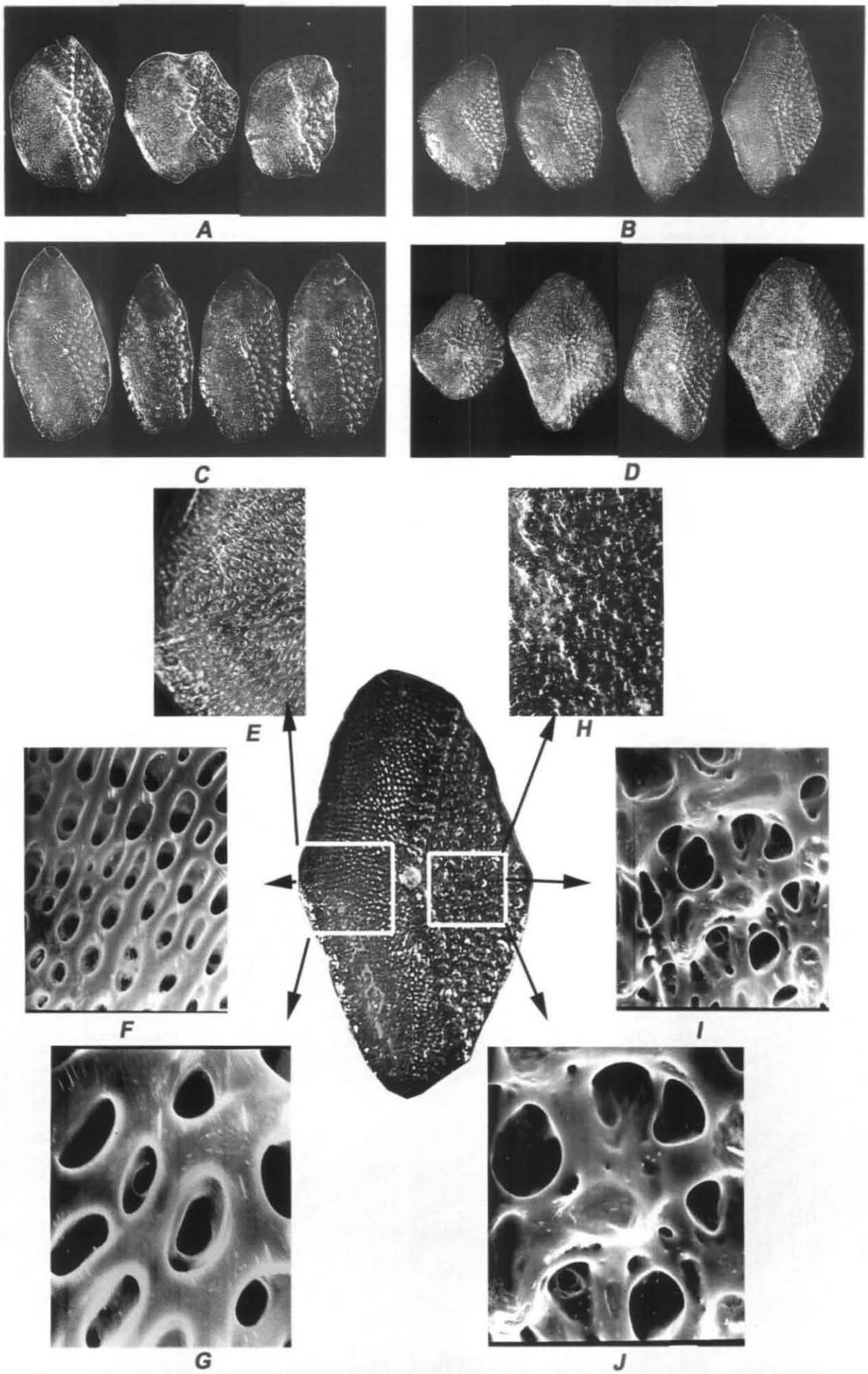
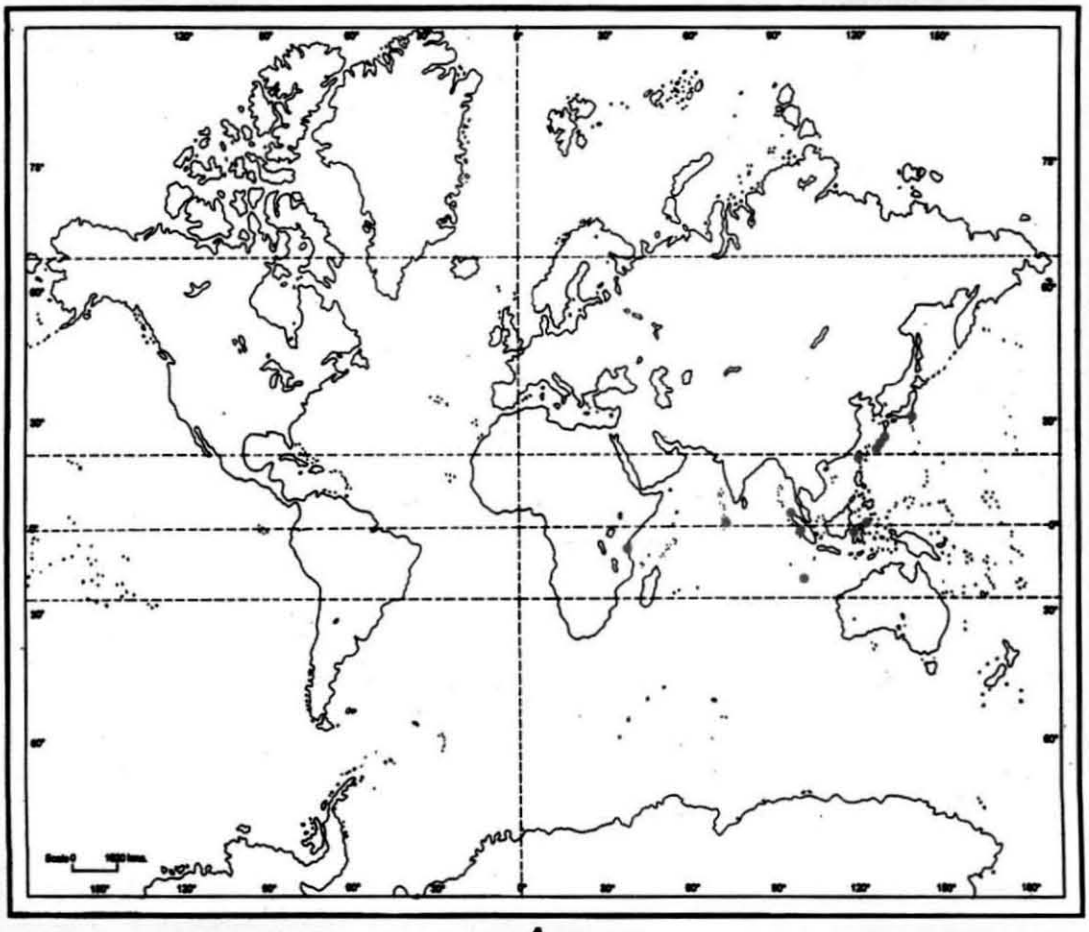
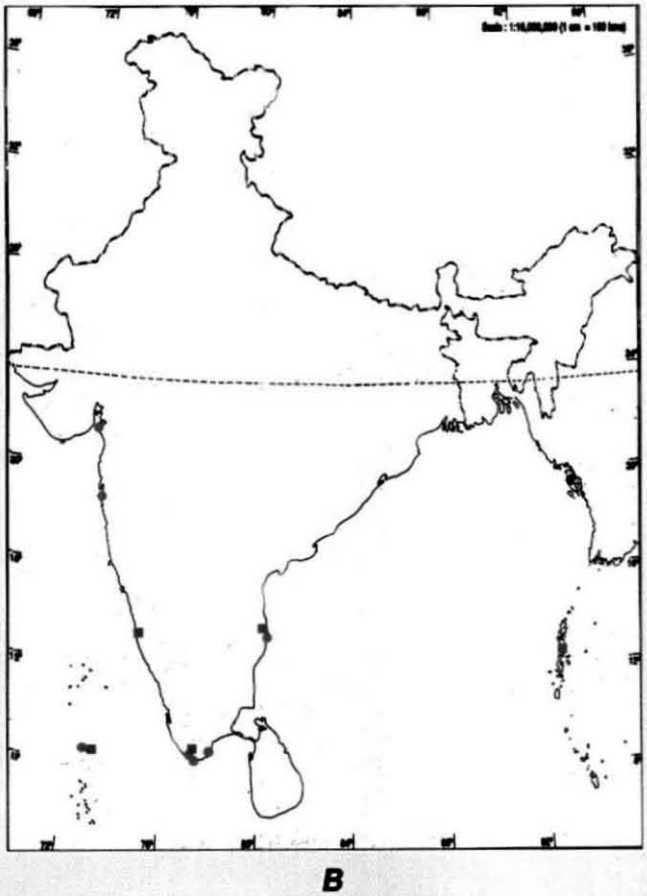


Figure 25. *Zenodon niger* (Ruppell, 1835): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x, 100x, 200x.



A



B

Figure 26. *Zenodon niger* (Ruppell, 1835): A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.3.Genus *Rhinecanthus* Swainson, 1839

(Type species *Rhinecanthus ornatissimus* Lesson, 1831, Zoologie, v. 2 p.114.)

Diagnosis

Anterior nostril tube like, directed forward. Groove before eye absent. Scales on cheek anteriorly square, posteriorly rectangular and rhomboid, with triangular scale in-between, arranged horizontally, having round protuberance. Body scales with ridges and retrose spines. Caudal peduncle equally long and deep, laterally elliptical, consists of 3-5 rows of antrose spines. Caudal rounded with lobes produced dorsally and ventrally.

Swainson (1839) erected the subgenus *Rhinecanthus* under the genus *Balistes,* with the following characters

> "First dorsal spine thick, obtuse, serrated or tuberculated; caudal fin rounded; pelvis with spine but no rays".

Swain (1888) designated *Rhinecanthus ornatissimus* (Lesson, 1831) as the type species. Bleeker (1866) treated *Rhinecanthus* as a synonym of subgenus *Balistapus* Tilesius (1820). Whitely (1930) also considered *Rhinecanthus* as a subgenus of *Balistapus* Tilesius (1820).

Fraser-Brunner (1935) elevated this subgenus to genus since he observed that:

> "With the exclusion of *Balistapus undulatus* these fishes form a very well-marked and sharply defined genus a salient feature being the pronounced rectangular form and rather long straight snout".

Further he added:

> "Third spine minute, caudal peduncle much constricted with numerous small spines in 2-4 rows".

Smith (1986) summarised the genus character as:

> "No groove before eye, enlarged plates behind gill opening, soft dorsal and anal low, 3rd dorsal spine very small, spines on caudal peduncle, cheek fully scaled, teeth unequal, notched, caudal peduncle with 3-5 rows of small spines".

During the present study specimens were collected from Lakshadweep and the distinctive features of *Rhinecanthus* and *Balistapus* are given in the table 3.

Table 3 Distinctive features of *Rhinecanthus* and *Balistapus*

S. No.	**Characters**	***Rhinecanthus***	***Balistapus***
1	Cheek scales	Larger than body scales square anteriorly, rhomboid posteriorly with some triangular in between.	Smaller than the body scale, rhomboid arranged vertically.
2	Nasal aperture	Anterior nasal aperture narrow tube directed forward, posterior nasal aperture circular.	Anterior nasal aperture is dome shaped with a pore at the center, posterior nasal aperture is a tube having circular opening.
3	Body scales	diamond shaped with 3 - 4 vertical rows of ridges and retrose spines.	diamond shaped with 3-4 vertical rows of ridges and retrose spines.
4	Caudal peduncle	cylindrical with 2-5 rows of black antrose spines.	laterally flat, with two rows of antrose spine, 6–8 spines in each row, anterior spines of both rows large.

From the above, it can be seen that

1. The distinctive characters put forward by Fraser-Brunner (1935) are valid to distinguish the two genera *Balistapus* and *Rhinecanthus* and they cannot be considered as synonyms.
2. Characters like nasal apertures, arrangement and morphology of scales on cheek, abdomen, caudal peduncle and body were not previously used for bringing out the variation between these two genera.
3. The genus *Rhinecanthus* can be redefined as

> "Scales on cheek square anteriorly, rhomboid posteriorly and triangular in between having round protuberance. Nasal aperture is a narrow tube directed forward, posterior nasal aperture circular. Body scales with 3 - 4 vertical rows of ridges or retrose spines. Caudal peduncle cylindrical with 2-5 rows of black antrose spines."

2.5.3.1. *Rhinecanthus aculeatus* (Linnaeus, 1758)

(Figure 30)

Balistes aculeatus Linnaeus, 1758, p.328.
Balistes aculeatus Day, 1878, p.690.
Rhinecanthus aculeatus Jones and Kumaran, 1980, p. 674, fig.573.

Diagnosis

The anterior nostril is a tube directed forward with a "V" shaped flap at the opening. Scales on cheek square anteriorly, rhomboid posteriorly, arranged horizontally. Body scale with ridges and retrose spine. Caudal peduncle equally long and deep, laterally elliptical, with 3 rows of antrose spines. Ventral flap present. Caudal round with dorsal and ventral lobes produced.

Material examined: 22 specimens from Minicoy, (14 females, 5 males, 3 indeterminate) ranging from 38 to 181 mm TL, 12 specimens from Kiltan, (10 Females, 2 Males) ranging from 94 to 162 mm TL, 9 specimens from Agatti, (9 Females) ranging from 105 to 215mm TL, (Fig.30.D), one specimen from Lakshadweep Islands, (Female) of length of 118 mm TL, one specimen from Kavaratti, (Female) of length of 203 mm TL, five specimens from Kavaratti, CMFRI Reg. No. LA-F-154/480, of lengths 121, 143, 147, 160, 162 mm TL, (Fig. 30.B), four specimens from Minicoy, CMFRI Reg. No. LA – F-154/480, of lengths 93, 128, 137, 195 mm TL, one specimen from Kalpitti, CMFRI Reg. No LA-F-154/480, of length of 175 mm TL, one specimen from Suheli, CMFRI Reg. No LA-F-154/480, of length of 108 mm TL, two specimens from Agatti, ranging CMFRI Reg. No.LA-F-154/480, of lengths 105,133 mm TL.

Additional material examined: 1 specimen from Andaman, ZSI Reg. No. 2253, of length of 191 mm TL, collected by Dr. F. Day (Fig. 30.C).

Description

D. III, i, 22-26; P. i, 10-13; ventral spines 8-14; A. i, 19-23; C. ii, 10; gill rakers 16-19; number of scales from origin of second dorsal to base of anal 14-17; lateral line scales 20-47; scales round the caudal peduncle 9-12.

As percent of head: Head height 94.64-118.60 (105.90); head width 41.94-57.69 (47.73); orbit 11.59-30.77 (18.03); interorbital 20.51-28.00 (23.15); postorbital 1.75-28 (3.17). The regressions of different head dimensions on head are given in figure 27.

As percent of standard length: Depth 36.25-43.75 (40.37); head 35.14-45.24 (41.41); snout 26.67-37.69 (33.91); predorsal length (I) 39.39-46.22 (42.49); predorsal length (II) 66.67-74.65 (70.14); preanal length 68.18-74.24 (71.86); post dorsal length (I) 28.72-46 (38.75); post dorsal length (II) 9.09-46.00 (5.82); base of first dorsal 12.50-39.39 (18.68); base of second dorsal 21.13-27.27 (24.05); base of anal 18.18-24.68 (22.40); second dorsal 9.09-15.56 (11.02); anal 8.87-12.93 (10.64); pectoral 10.61-72.41 (19.42); caudal peduncle 6.67-9.52 (8.26). The regressions of different body dimensions on standard length are given in figure 28 & 29.

Body rhomboid. Head profile, straight, prominent chin. Eye placed high. Upper lip fleshy, soft, broad and covers the lower lip. Lower lip is broad and thin. inter orbital flat. First dorsal spine compressed laterally, anterior broad with small spinules at base and blunt large spinules at tip. Third spine minute. The anterior and posterior nostrils placed in separate depressions (Fig.31.A). All the teeth rectangular with the upper side straight but one side slightly longer than other (Fig.31.B).

There are 3-5 scales in a rectangular region above pectoral, each of these scales are engraved with longitudinal ridges. Gill opening oblique. Gill rakers have broad base, short, hyaline, blunt tipped and having globular protuberance towards the inside (Fig. 31.C). Second dorsal and anal short, thin, rectangular with edges round. Caudal round with lobes produced dorsally and ventrally in fishes having TL of 150- 200 mm and round in fishes having TL of 40 – 100 mm. Pectoral fin rounded.

The scales on check have round protuberances arranged in 3-8 rows vertically (Fig. 31.D & Fig.32.A). The body scales have 3 - 4 vertical rows of ridges and blunt

retrose spines (Fig. 31.E & Fig. 32.B). The ultra structure of the anterior margin of the body scale shows round and triangular projections arranged in semicircular rows (Fig. 32.E-G) and the posterior margin has blunt retrose spines (Fig. 32.H-J). The scales on abdomen are rhomboidal arranged obliquely, with round protuberances arranged in 3-5 oblique rows (Fig. 31.F & Fig.32.C). The caudal peduncle has two type of scales 1) scales having 3-5 rows of antrose spines and also an antrose spine at the anterior middle. 2) Scales having 3-5 vertical rows of blunt retrose spines (Fig.31.G & Fig. 32.D).

Ventral flap is narrow, translucent, supported by ventral spines (Fig. 31.H) Pelvic spine, stout broad with 3 to 4 rows of sharp ridges at the centre and small spinules dispersed all over the spine with stellate spines at the posterior edges.

Colour

Body dorsally brown and ventrally white. Inter orbital with 4 bands of blue and three black bands. At the center of the body is a dark brown to black blotch, from which two black bands, meets the base of the second dorsal and anal. From base of anal arises 4 white bands, which meet the central black blotch. Three blue lines extend from interorbital bands and ends till the base of pectoral, between these lines are two bands anterior one light brown and posterior one black. Lips yellow, just above upper lip a blue and yellow band is present which reach the base of the pectoral crossing the cheek. On the caudal peduncle are arranged 3 rows of black antrose spines, which are placed on a white patch. Caudal fin, second dorsal, anal and pectoral fins transparent with light pink color. Pelvic spine pink. Anus surrounded by dark blue ring (Fig. 30.A).

Colour in the preserved specimens: Formalin preserved specimens have light brown, the interorbital with a dark brown band with 3 slightly darker bands at the anterior. Brown band starting from the eye reach the branchial aperture. A dark brown blotch occupies the centre of the body from which originates 2 bands towards dorsal base and two bands towards anal base. Four white bands originating from anal base reaches the central blotch. Except for the first dorsal which is dark brown rest of fins are light brown. The antrose spines at caudal peduncle black (Fig. 30.D).

Alcohol preserved Specimen has light brown color with four white bands arising from base of anal reaches the center of the body. Inter orbital has 4 white bands which are placed between 3 dark brown band. Two white bands originating from the interorbital area reaches the base of the pectoral. Another white band is found at the center of the caudal peduncle, on which 3 rows of spine (dark brown) is placed. The lips surrounded by white band (Fig. 30.C).

Distribution

India (Linnaeus, 1758); Suva, Nukulau Island, (Fiji), New Guinea, Solor, Java, Cocos, Nias, Celebes, Flores, Solor, Buro, Ambonia, Banda, Sumbawae Island Batavia at Bima, Zimbabwe Island (Java), Pirman (Sumatra) (Bleeker, 1848, 1852, 1853, 1857,1859, 1860); West coast of Africa, Zanzibar, Mauritius, Island of Johanna, Moluccas, Ambonia, china sea, Fuji Islands, Micronesia, Seychelles (Gunther, 1870); Samoa and Laysan (Steindacher, 1900); Agana, Guam (Seale, 1901); Tahiti, Rarotonga, Fate, Raiatea, Nukuhiva, Marquesas (Seale, 1906); Cuyo Cuyo Islands Sulu sea (Philippines) (Jordan and Richardson, 1908); Makassar, Kabaladua (Borneo bank), Sanguisiapo, Tawi – Tawi Island (Sulu Archipelago) (Max Weber, 1913); Itoman, Okinawa Island (Japan) (Schmidtt, 1930); Masthead Island, Queens land Island, Port Moresby, Papua, Vanikoro, Santa Cruz group, Vate and Aneiteum, New Hebrides, Samoa, Fiji, Bougainville Island, Solomons (Whitely, 1934); Makatea, Tuamotu Islands, Tahiti, Society Islands (Herre, 1936); Samoa (Fowler, 1936); Solomon Island (Rofen, 1958); Bacon (Philippines) (Everman and Seale, 1907); Ishigaki Island, Ryukyu Island, Okinawa Island (Japan) (Matsuura, 1980); Maldives (Jones *et al.*, 1981); Sesoko Island (Japan) (Kuwamura, 1991); Nanwan, Taiwan (Shoa *et al.*, 1994); Cocos Island (North Western Australia) (Allen and Smith 1996) (Fig. 33.A & B).

Remarks: In Minicoy these fishes are found in the sandy, coral area of the lagoon, hiding in the corals.

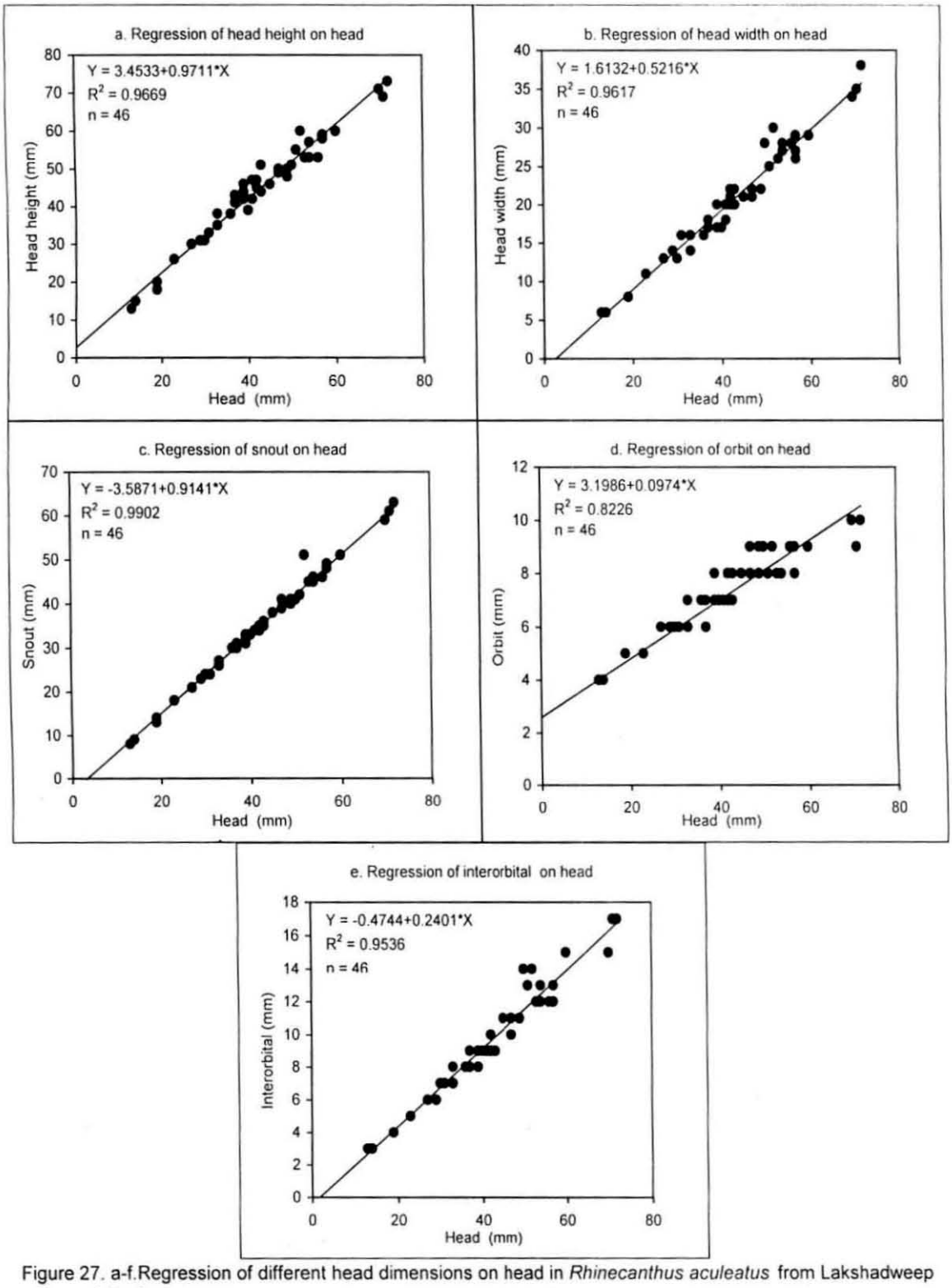


Figure 27. a-f.Regression of different head dimensions on head in *Rhinecanthus aculeatus* from Lakshadweep Islands.

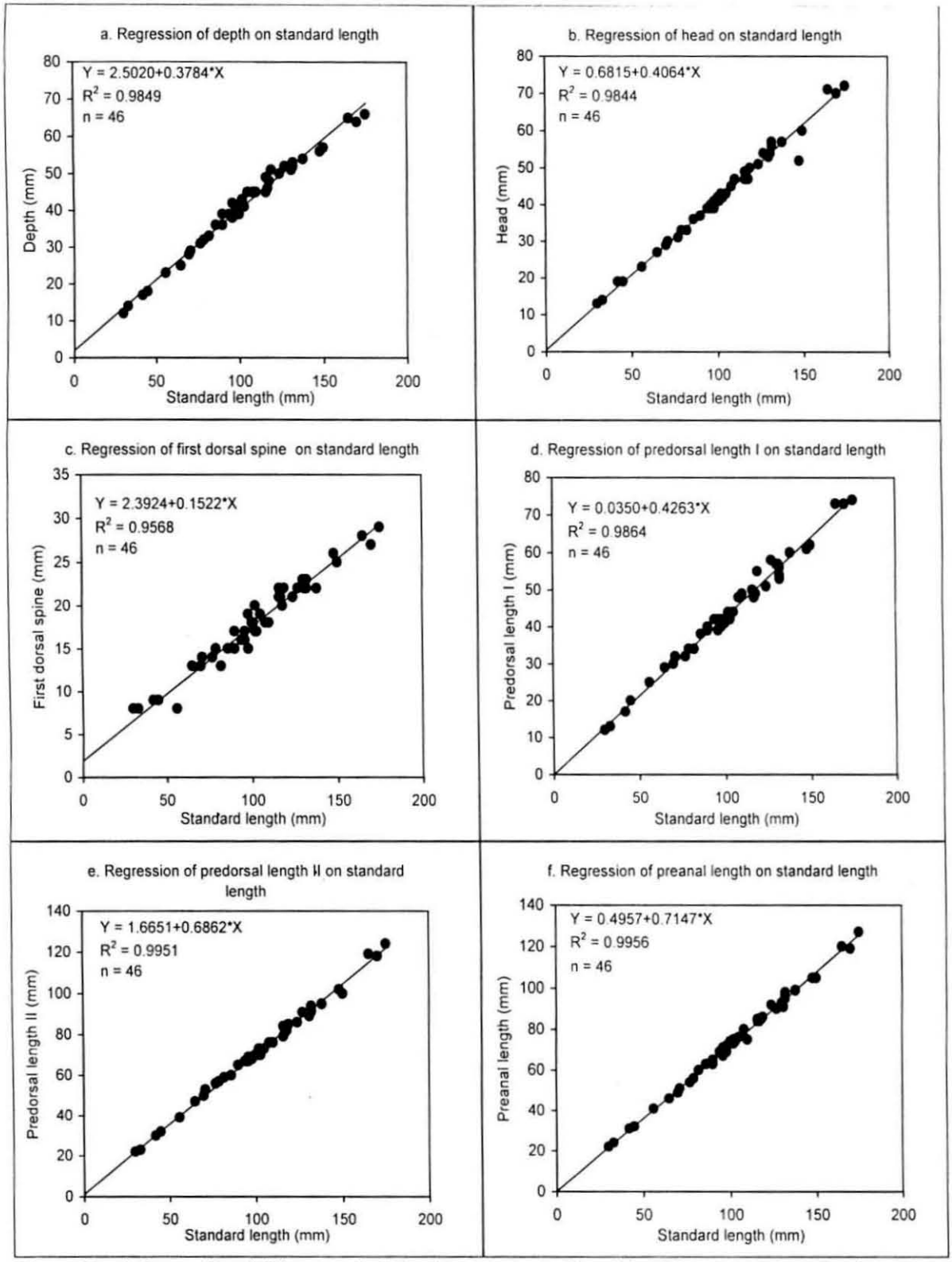


Figure 28. a-f. Regression of different body dimensions on standard length in *Rhinecanthus aculeatus* from Lakshadweep Islands

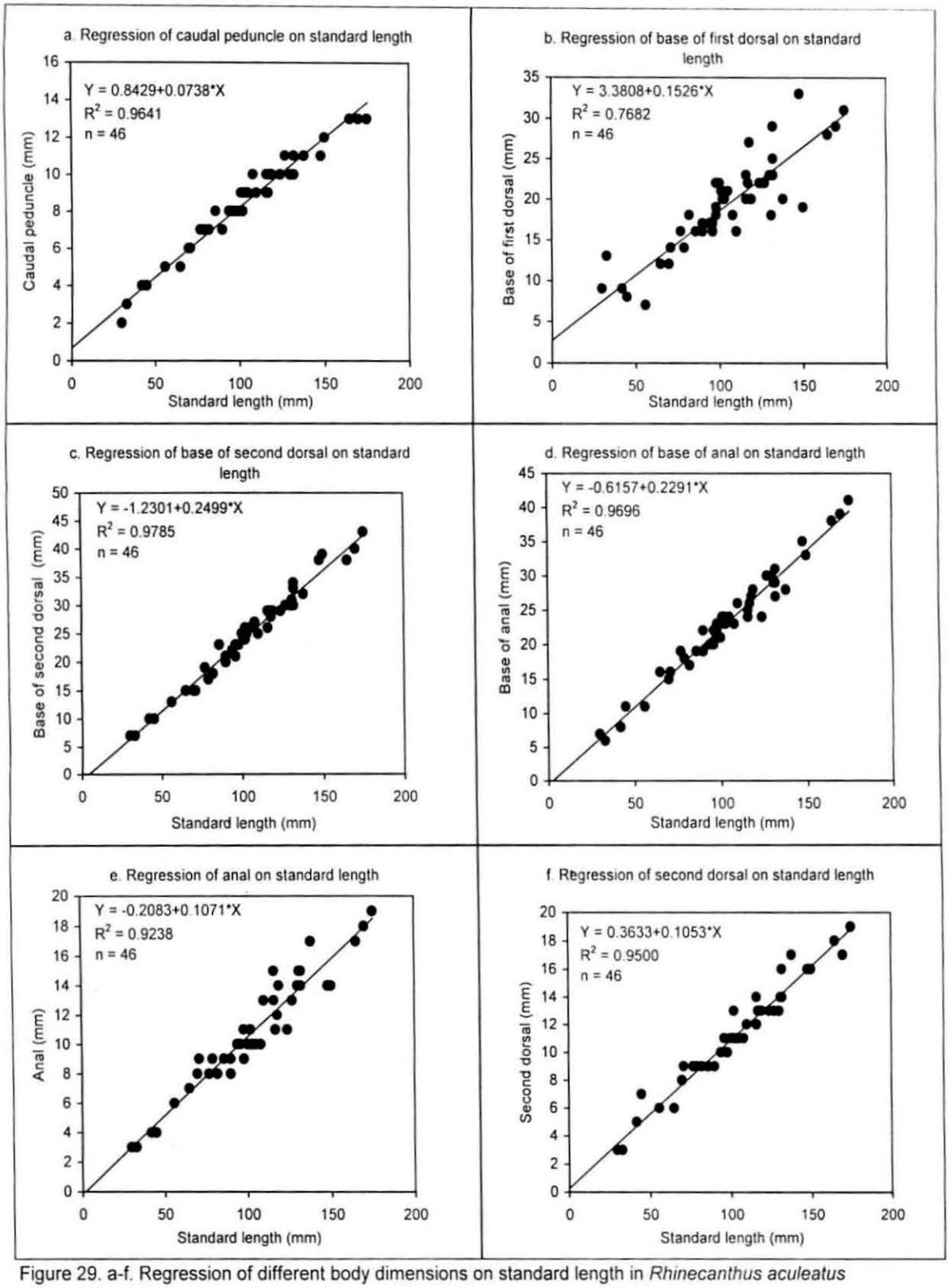
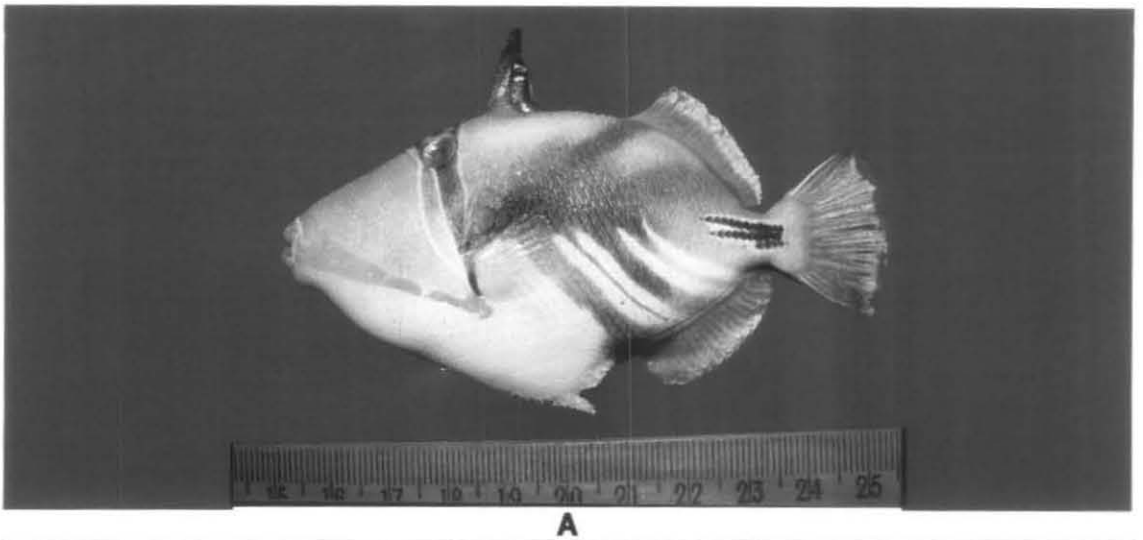
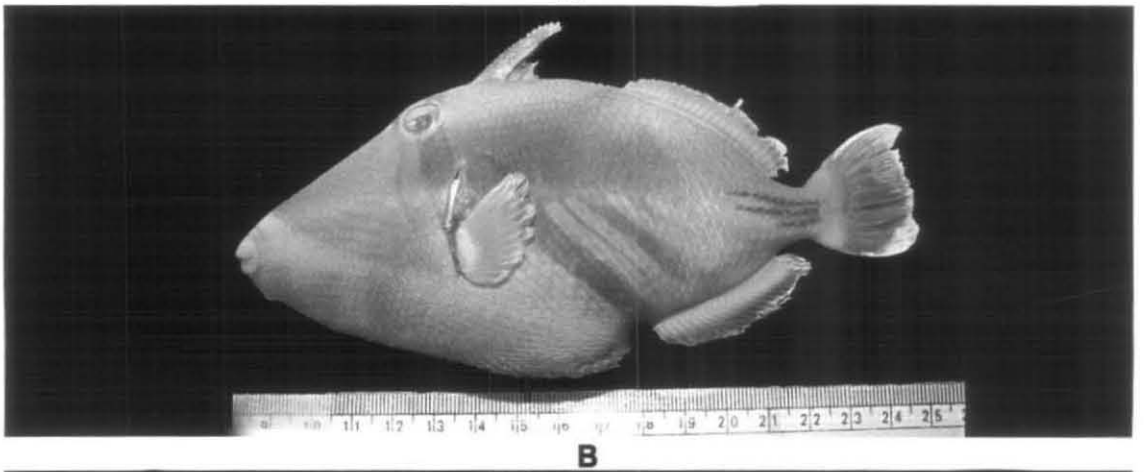


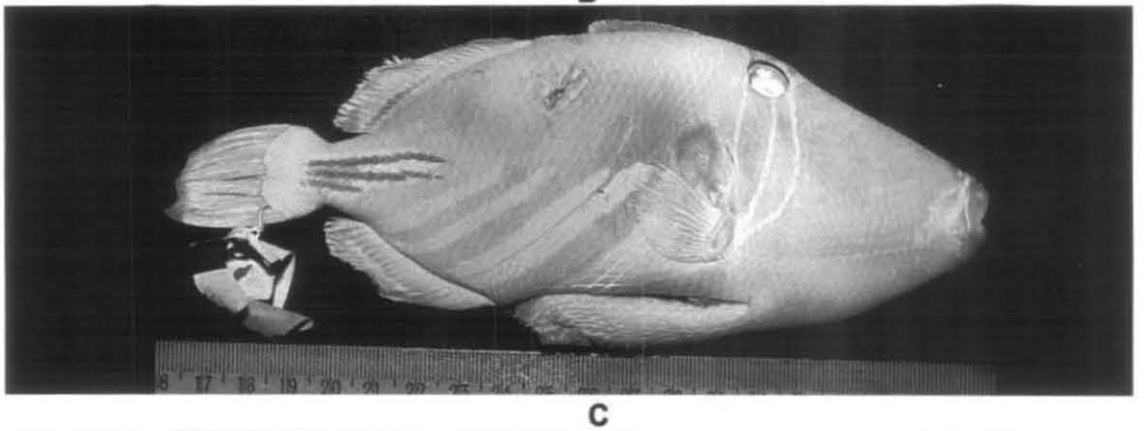
Figure 29. a-f. Regression of different body dimensions on standard length in *Rhinecanthus aculeatus* from Lakshadweep Islands



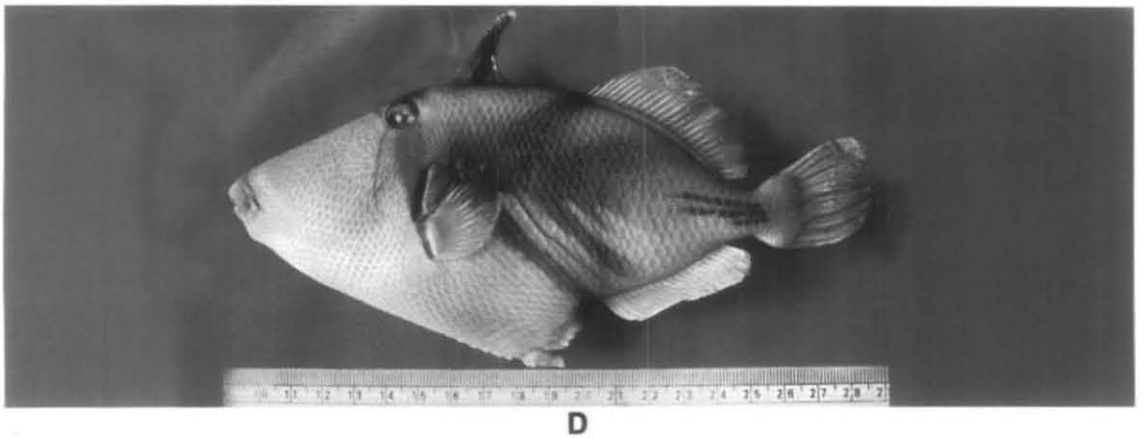
A



B



C



D

Figure 30. *Rhinecanthus aculeatus* (Linnaeus,1758): A. From MInicoy 110 mm TL, B. From Kavaratti CMFRI-LA-154/480 162 mm TL, C. From Andaman ZSI Reg. No. 2253 191 mm TL, collected by Dr. F. Day, D. From Agatti 203 mm TL.

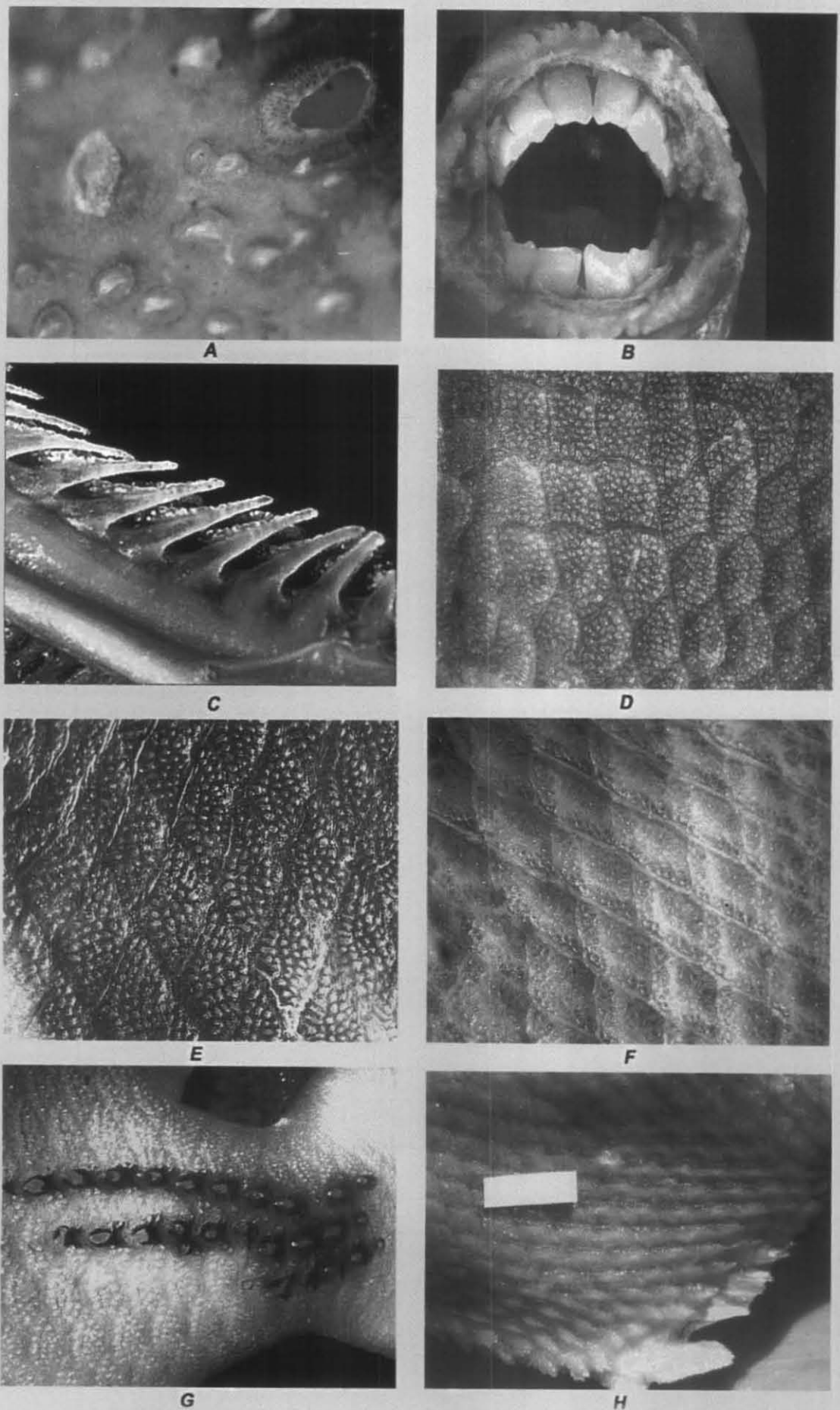


Figure 31. *Rhinecanthus aculeatus* (Linnaeus, 1758): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

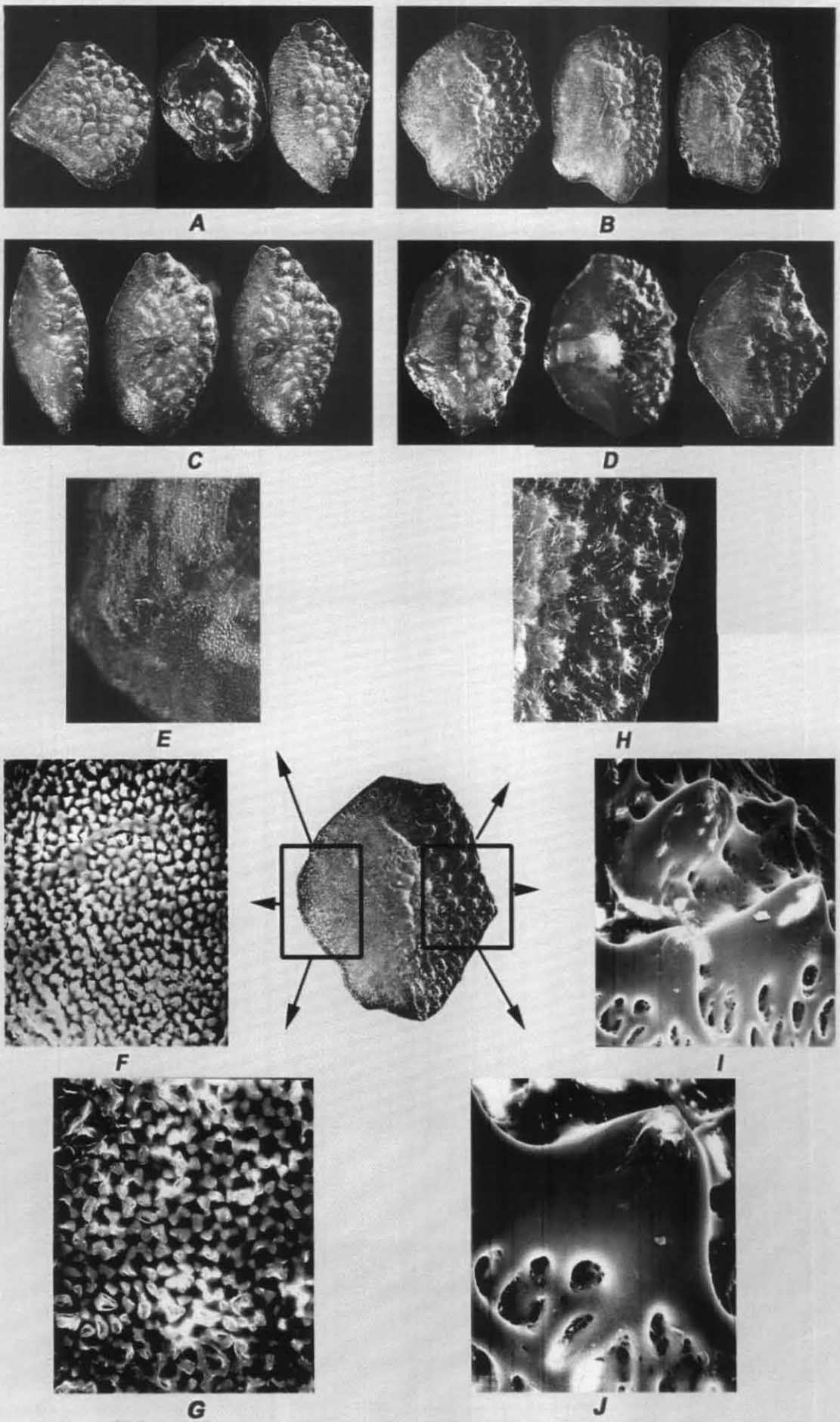
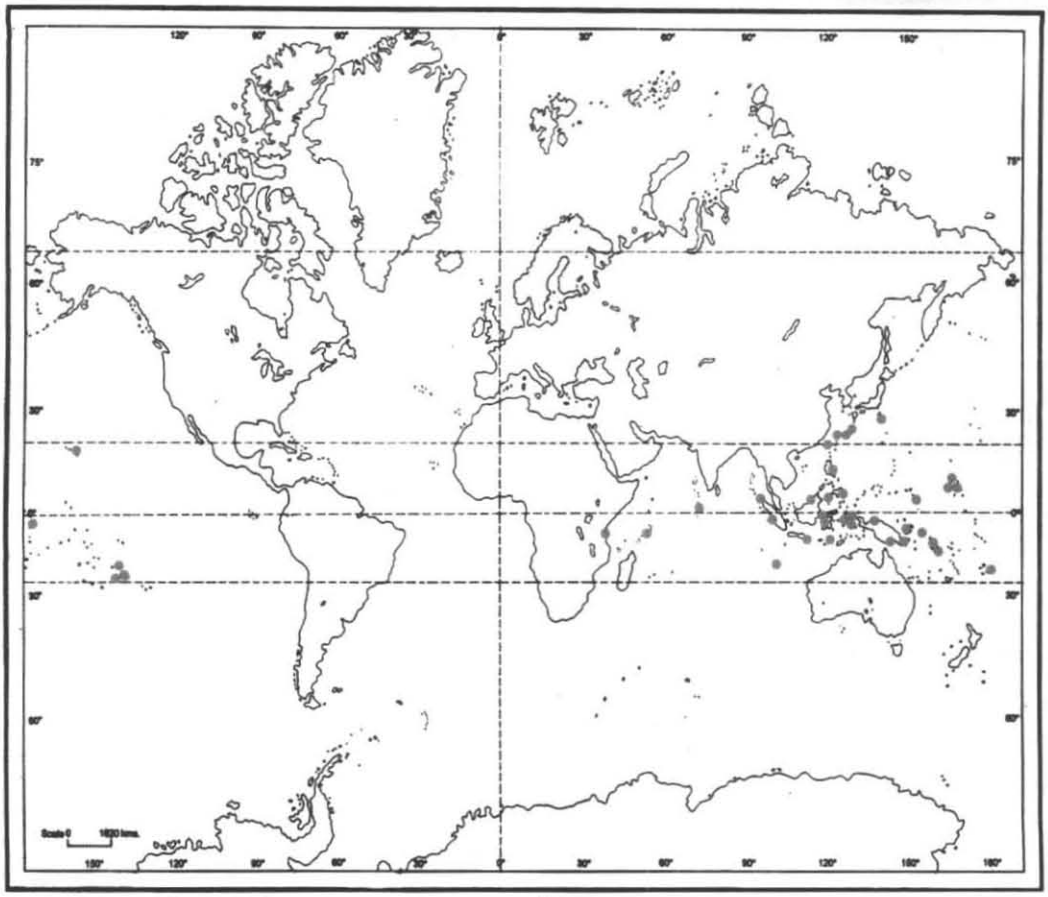
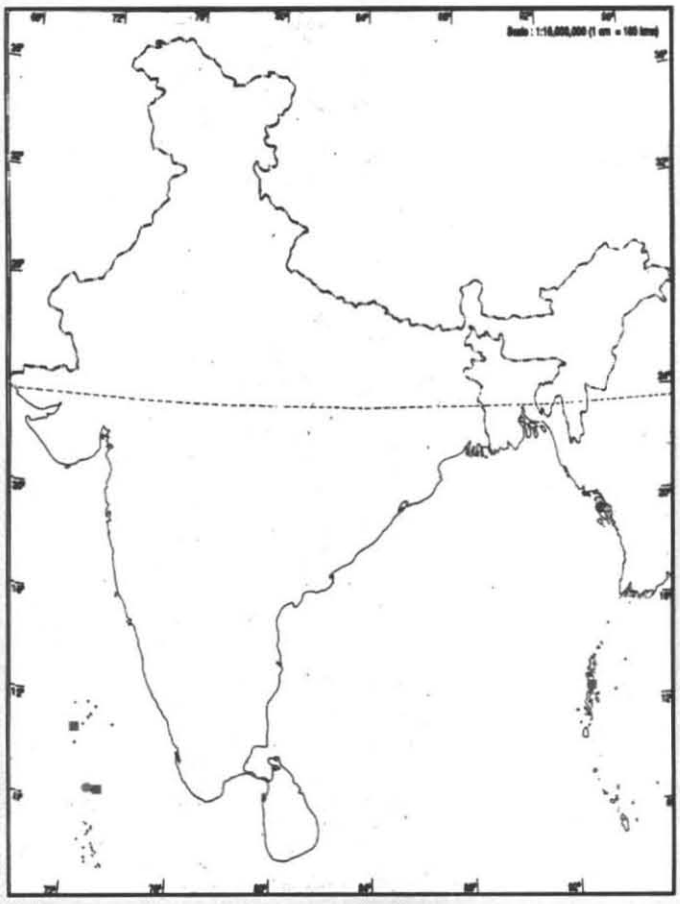


Figure 32. *Rhinecanthus aculeatus* (Linnaeus, 1758): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.



A



B

Figure 33. *Rhinecanthus aculeatus* (Linnaeus, 1758), A. Distribution in world, B. Distribution in India, ■ on Indian map indicates collections made by previous authors, ● on Indian map indicates the places from where specimens were collected

2.5.3.2. *Rhinecanthus echarpe* (Lacepede, 1798)

(Figure 34)

Balistes echarpe Lacepede, 1798, p.333, 352.
Balistes rectangulus Day, 1878, p.691.
Rhinecanthus rectangulus Jones and Kumaran, 1980, p. 674, fig.573.

Diagnosis

Nostrils anterior tube directed forward. Groove before eye absent. Scales on cheek square at the anterior and rectangular at the posterior with triangular scale in between, arranged horizontally, with round protuberance. Body scales with blunt retrose spines. Caudal peduncle equally long and deep with 4-5 rows of antrose spines arranged horizontally. Ventral flap present. Caudal round with lobes produced dorsally and ventrally.

Material Examined: 2 specimens from Minicoy, (1 male) of lengths 152, 165 mm, TL (Fig. 34.A).

Additional material examined: 1 specimen from Malay Archipelago, ZSI Reg. No. 2252, of length of 179 mm TL, collected by Dr. F. Day (Fig. 34.B).

Description

D. III, i, 22-24; P. i, 12-13; ventral spines 11-12; A. i, 19-20; C. ii, 10; gill rakers 17-20; number of scales from origin of second dorsal to base of anal 16-19; lateral line scales 35-49.

As percent of head: Head height 106.0-107.55 (106.77); head width 48.0–50.94 (49.47); orbit 16.0–16.98 (16.49); Interorbital 22.0–22.64 (22.32); postorbital 2.0–5.66 (3.83).

As percent of standard length: Depth 36.30–39.02 (37.66); head 39.26–40.65 (39.95); snout 33.33–34.96 (34.14); predorsal length (I) 39.02–40.74 (39.88); predorsal length (II) 66.67 (66.67); preanal length 70.37–73.17 (71.77); postdorsal length (I) 42.28–57.04 (49.66); postdorsal length (II) 8.13–8.89 (8.51); base of first dorsal 18.52–18.70 (18.61);

base of second dorsal 24.44–25.20 (24.82); base of anal 20.33–22.96 (21.64); second dorsal 9.63–12.20 (10.91); anal 11.11–11.38 (11.24); pectoral 11.11 –12.20 (11.65); caudal peduncle 8.15–8.94 (8.54).

Body rhomboid, head profile straight with a prominent chin. Eye placed high. Interorbital straight. Lips thick, fleshy, continuous at the corner, the upper lip covers the lower lip, which is thin and flat. First dorsal spine long, stout, laterally compressed, anteriorly broad with short ridges at the base and long ridges at tips, small spinules present on the lateral side. Third spine minute and less than ¼ the first spine. Nostrils slightly elevated (Fig. 35.A). The teeth are rectangular with the upper side straight with one side slightly elevated (Fig. 35.B).

Two rectangular and a triangular scale placed above the base of the pectoral. Gill opening oblique. Gill rakers are short, blunt, hyaline and having hairy projection towards the inside (Fig. 35.C). The second dorsal and anal fin rectangular and anteriorly elevated, edges round and transparent. Pectoral rounded.

Scales on cheek have 3-8 vertical rows of small round protuberance (Fig. 35.D & Fig.36.A). Body scale has 5-6 horizontal rows of blunt retrose spines (Fig. 35.E & Fig. 36.B). The ultra structure of the anterior margin of the body scale shows a network of fibers and circular depressions (Fig. 36.E-G) and the posterior margin has blunt retrose spines and ridges (Fig.36.H-J). Scales on abdomen are rhomboid with round protuberances arranged in 3-5 oblique rows (Fig.35.F & Fig.36.C). Scales on caudal peduncle are of two types 1) wedge shaped scales with an antrose spine at the anterior middle and 1-2 vertical rows of ridges, 2) diamond shaped scales having 4-5 vertical rows of ridges (Fig. 35. G & Fig. 36.D).

The ventral spines are laterally compressed, arranged in a single row with spines from both sides alternating (Fig.35.H). Pelvic spine rectangular with many antrose spinules at the anterior and retrose spinules at the posterior. This pelvic spine has two portions the anterior fixed portion and posterior movable portion.

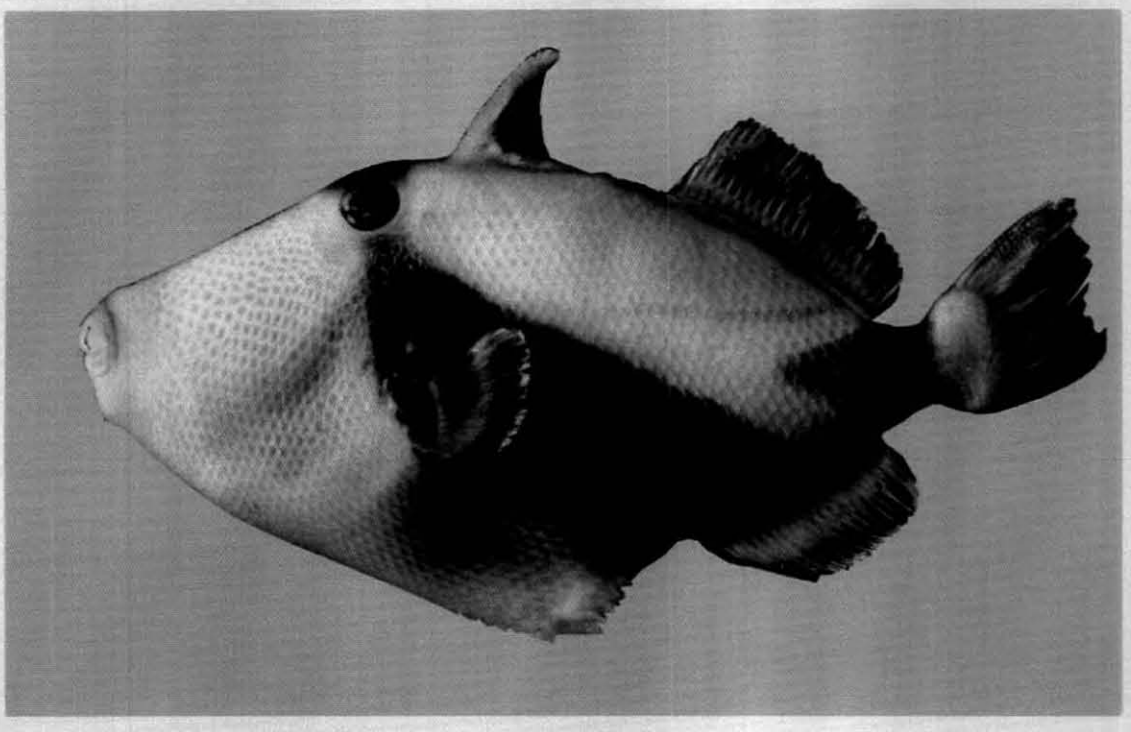
Colour

The fish is uniformly brown. A black band at the interorbital, which has three white bands, one at the anterior middle and the posterior. A wide black band extending from eye to the base of anal passes through the base of pectoral base. A black band occupies the caudal peduncle, which is triangular, bordered with white. The first dorsal black. Pectoral and caudal transparent with a brown ting. Second dorsal and anal transparent.

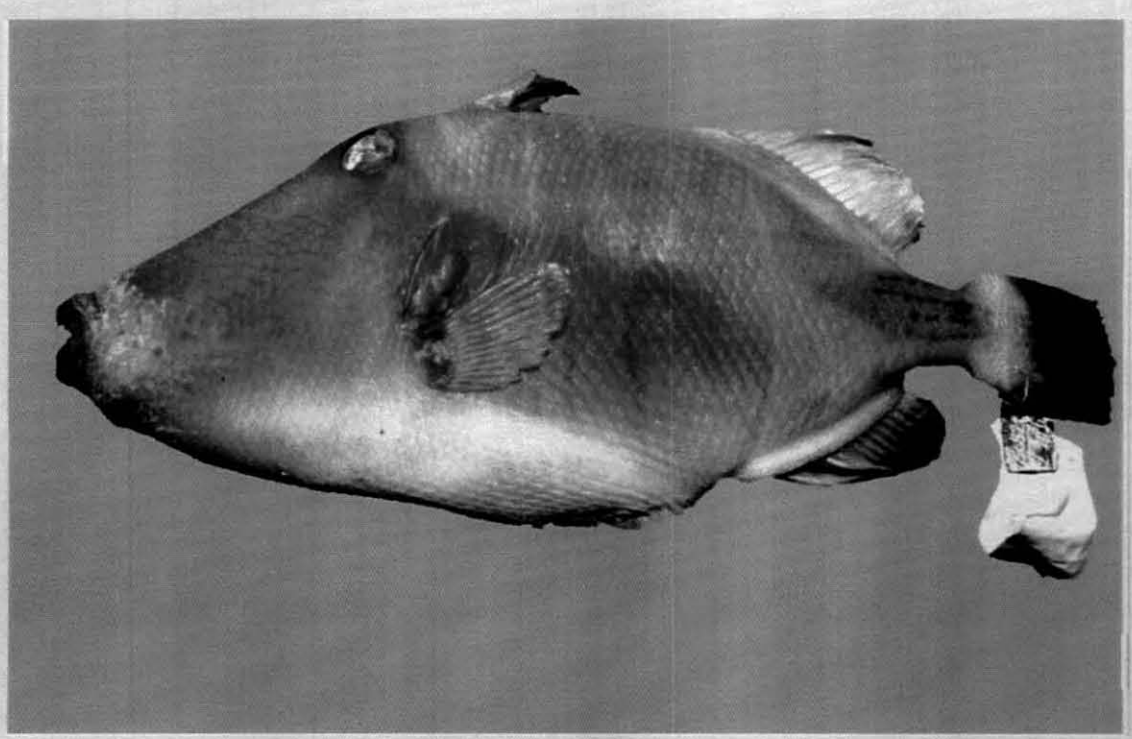
Colour of preserved specimen: Body uniformly light brown, brown band at the interorbital. A brown band originates from eye and reaches to anal base, passing through the pectoral base. Caudal peduncle has triangular brown band. First dorsal fin black. Second dorsal and anal fin transparent pectoral and caudal brown (Fig. 34.A).

Distribution

Indian Ocean (Bloch and Schneider, 1801); Ambonia, New guinea (Bleeker, 1857, 1859); Zanzibar, East Indian Archipelago (Gunther, 1870); Malay Archipelago (Day, 1878); Honolulu (Steindacher, 1900); Honolulu (Jenkins, 1904); Honolulu (Hawaiian Islands) (Jordan and Everman, 1905); Fate (New Hebrides) Nukuhiva (Marquesas Islands) (Seale, 1906); Agana (Guam) (Seale, 1901); Beo (Island Karakelang), Lucipara Island (Max Weber, 1913); Calayan Island (Philippines) (Jordan and Richardson, 1908); Bikini Atoll, Eniwetok Atoll, Rongelap Atoll, Rongerik Atoll, Kwajalein Atoll, Likiep Atoll, Rota Island (Schultz, 1966); Okinawa Island, Ryukyu Island, Ishigaki Island, Kuroshima Island (Matsuura, 1980); Sesoko Island (Japan) (Kuwamura, 1991);. Maldives (Jones *et al.*, 1981); Lutao (Taiwan) (Shoa *et al.*, 1994); Cocos Island (North Western Australia) (Allen and Smith, 1996) (Fig. 37.A & B).



A



B

Figure 34. *Rhinecanthus echarpe* (Lacepede,1798): A. From MInicoy 152 mm TL, B. From Malay Archipelago ZSI Reg. No. 2252 179 mm TL, collected by Dr. F. Day.

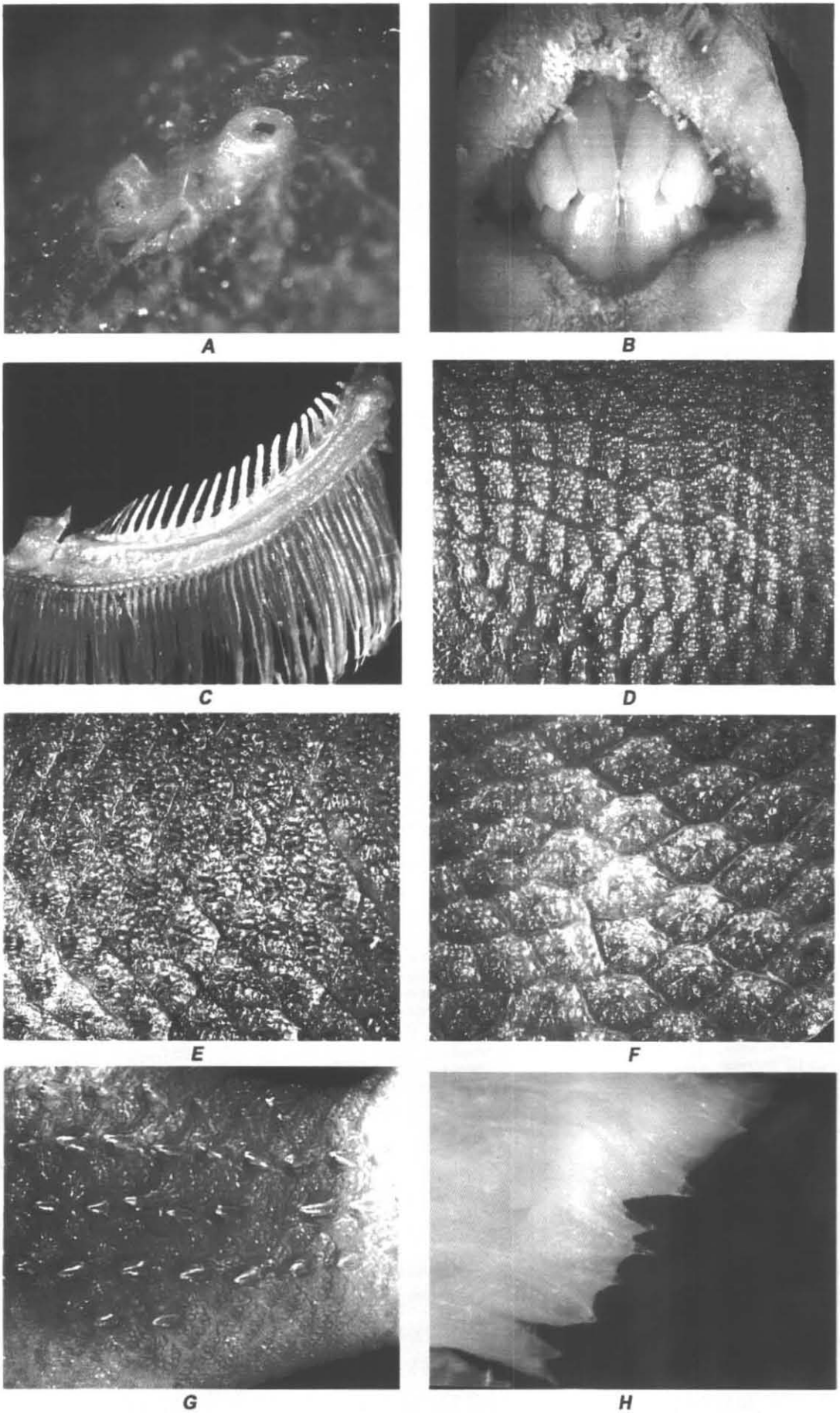


Figure 35. *Rhinecanthus echarpe* (Lacepede,1798): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

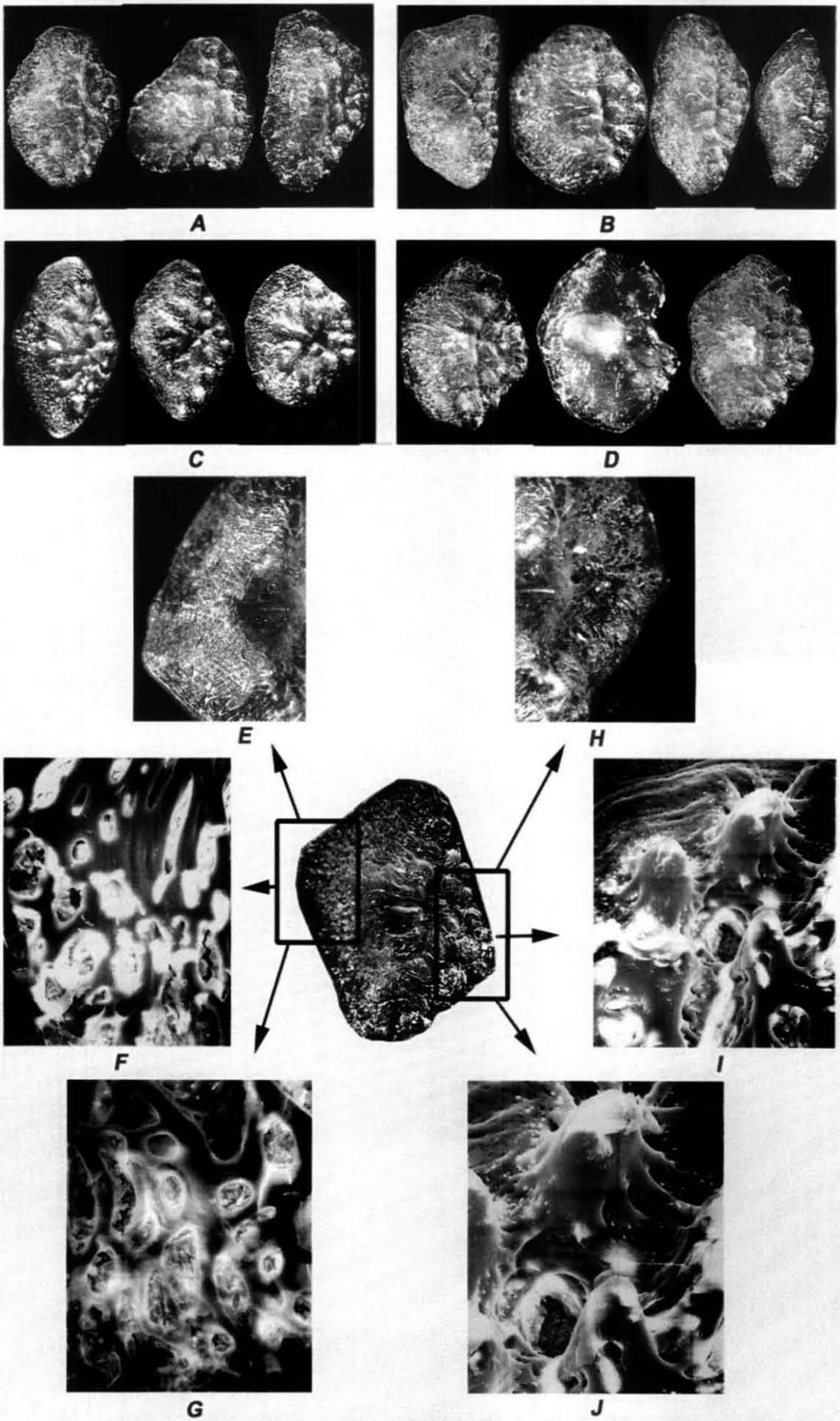
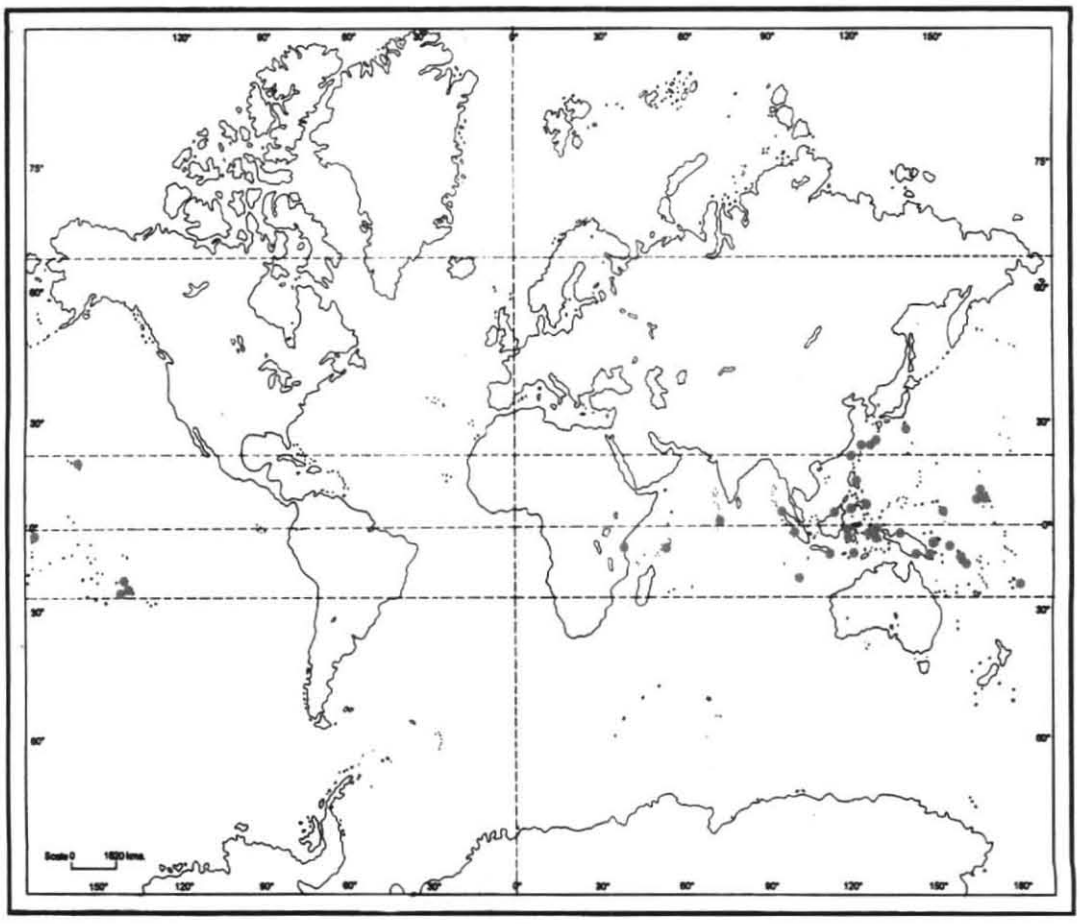
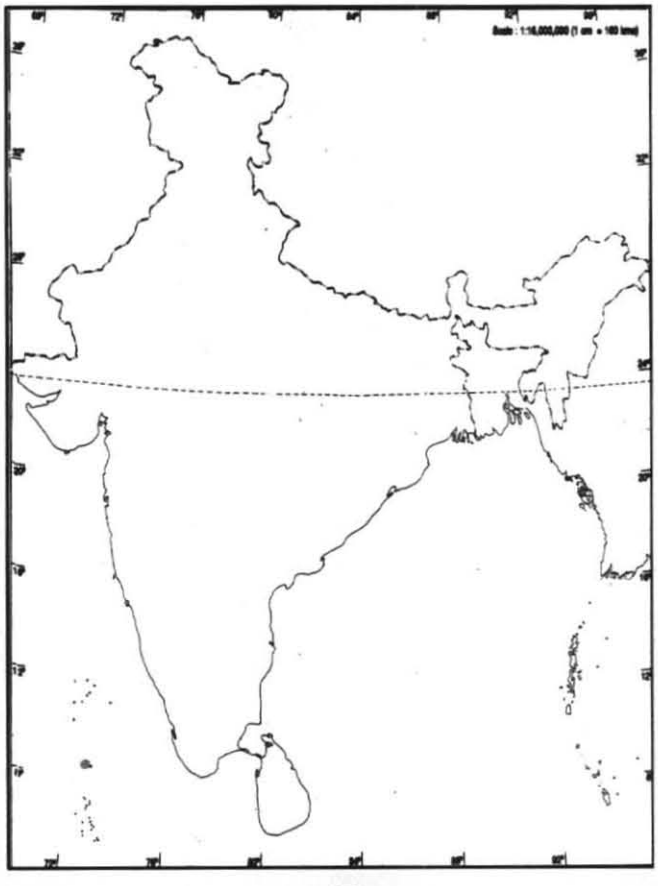


Figure 36. *Rhinecanthus echarpe* (Lacepede, 1798): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E - G. Anterior margin of body scale 40x,100x, 200x, H - J. Posterior margin of body scale 40x, 100x, 200x.



A



B

Figure 37. *Rhinecanthus echarpe* (Lacepede, 1798), A. Distribution in world, B. Distribution in India, ● on Indian map indicates the places from where specimens were collected.

2.5.4. Genus *Melichthys* Swainson, 1839

(Type species *Balistes ringens* Osbeck, 1765.)

Diagnosis

The anterior nostril conical with a circular opening at the tip. Groove before eye. Scales on cheek rectangular to diamond shaped, arranged in vertical rows and having horizontal ridge. Body scales with horizontal ridges. Caudal peduncle deeper than long, laterally elliptical having 6 - 8 rows, of horizontal ridges. Ventral flap absent. Caudal truncate.

2.5.4.1. *Melichthys indicus* Randall and Klausewitz, 1973

(Figure 41)

Melichthys indicus Randall and Klausewitz, 1973, p.57-69, fig.5.
Balistes ringens Bleeker, 1860, p. 69.
Melichthys niger Jones and Kumaran, 1980, p. 666, fig.567.

Material examined: 23 specimens from Minicoy, (15 females, 7 male) ranging from 155 to 210 mm TL.

Additional material examined: 1 Specimen from Lakshadweep, CMFRI Reg. No. 554, 200 mm TL (Fig. 41.B) collected by Jones and Kumaran.

Description

D. III, i, 30-34; P. i, 13-14; ventral spines 0–26; A. i, 26-29; C ii, 10; gill rakers 26-28; number of scales from origin of second dorsal to base of anal 19–24; lateral line scales 30–77; scales round the caudal peduncle 12–18.

As percent of head: Head height 141.82–163.27 (152.77); head width 62.50–78.57 (68.76); orbit 18.18–20.93 (19.23); interorbital 30.95–39.13 (35.03); postorbital 2.17–14.58 (8.13). The regressions of different head dimensions on head are given in figure 38.

As percent of standard length: Depth 43.90–48.67 (45.90); head 30.67–43.31 (32.55); snout 21.97–24.82 (23.70); predorsal length (I) 28.00–32.32 (30.09); predorsal length (II) 61.22–66.01 (63.46); preanal length 63.80– 70.00 (67.35); postdorsal length (I) 45.91–52.94 (50.19); postdorsal length (II) 2.61–5.49 (4.44); base of first dorsal 15.85–24.09 (19.73); base of second dorsal 29.88–34.36 (32.10); base of anal 25.97–32.94 (28.07); second dorsal 15.82–18.82 (17.39); anal 14.12–18.75 (16.24); pectoral 8.16 –10.67 (9.61); caudal peduncle 7.65–9.33 (8.30). The regressions of different body dimensions on standard length are given in figure 39 & 40.

Body oval, deep. Head profile, convex with a prominent chin. Lips flat, thin. Inter orbital straight. Groove equal to orbit, deep at the centre, shallow at anterior, broad towards posterior, directed downwards. First dorsal spine short, stout, blunt, laterally compressed. Anterior base has long ridges, and at the middle are present small round protuberances, which spread laterally, tip has large round protuberances. Third dorsal spine, less than ¼ the length of first spine. Nostrils placed in a shallow depression, anterior nostril has a semicircular flap on the opening (Fig.42.A). The teeth are rectangular with a convex upper side (Fig. 42.B).

Four to five large scales, thin, engraved and arranged in a rectangular region above pectoral base. Gill opening vertical. The gill rakers are thin, hyaline with pointed tips (Fig. 42.C). The second dorsal, and anal fins are thick at base and thin towards the tip, anteriorly elevated and posteriorly short with edges round, with a rectangular shape and convex profile. Pectoral fin rounded, black.

Scales on cheek have 3–4 vertical rows of horizontal ridges (Fig.42.D & Fig. 43.A). Body scales have 3-5 vertical rows of transverse ridges (Fig.42.E & Fig. 43.B). The ultra structure of the anterior margin of the body scale shows broad fibres and

circular depressions (Fig. 43.E-G) and the posterior margin has ridges (Fig. 43.H-J). Scales on abdomen are rectangular and rhomboid with short ridges arranged in 3-5 vertical rows (Fig. 42.F & Fig. 43.C). Scales on caudal peduncle have 10-20 horizontal ridge and 3-4 short pointed and blunt ridges at the centre (Fig. 42.G & Fig. 43.D).

The ventral spines are very short and pointed in few specimens, in others the spines are absent and the region is thickened (Fig. 42.H). Pelvic spine short blunt.

Colour

Body black. Second dorsal and anal fin base has a white band. A blue band is seen just at the centre of cheek passing obliquely downward up to the ventral portion of cheek. Six blue lines radiate from the eye in six different directions dorsally (Fig. 41.A).

Colour of the preserved specimens: Formalin preserved specimens are brown. First dorsal, second dorsal, anal fins are white. Caudal and pectoral fin are brown with edges brownish white. An oblique streak on cheek is reddish brown (Fig. 41.B).

Distribution

Aldabra, Seychelles; Poivre, Seychelles; Addu–Attol, Maldives; Trincomalee, Ceylon; Tropicarium, Ceylon; Tillanchong, Nicobar; Priaman, West coat of Sumatra; Goy huyong, Similian Island, Thailand (Fig. 44 A & B).

Taxonomic Note: According to Randall and Klausewitz (1973)

> "This species resembles *M. niger* in colouration-particularly in preservative-and has been confused with it by a number authors. In its caudal shape, counts, and weakly developed ridges along posterior scale rows, however it is closer to *vidua*".
>
> "All of our specimens have come from the Indian Ocean, SANZO's specimens from the southern Red Sea. In the belief that the species may be confined to this ocean (including the western Indo-Australian Archipelago and the southern Red Sea), we have named it *indicus*".

Jones and Kumaran described *Melichthys niger* from the Lakshadweep archipelago (CMFRI specimen Reg. No.554). On examination it was found that, this specimen was *Melichthys indicus* Randall and Klausewitz, 1973. Thus *Melichthys niger* of Jones and Kumaran becomes the synonym of *Melichthys indicus* of Randall and Klausewitz, 1973.

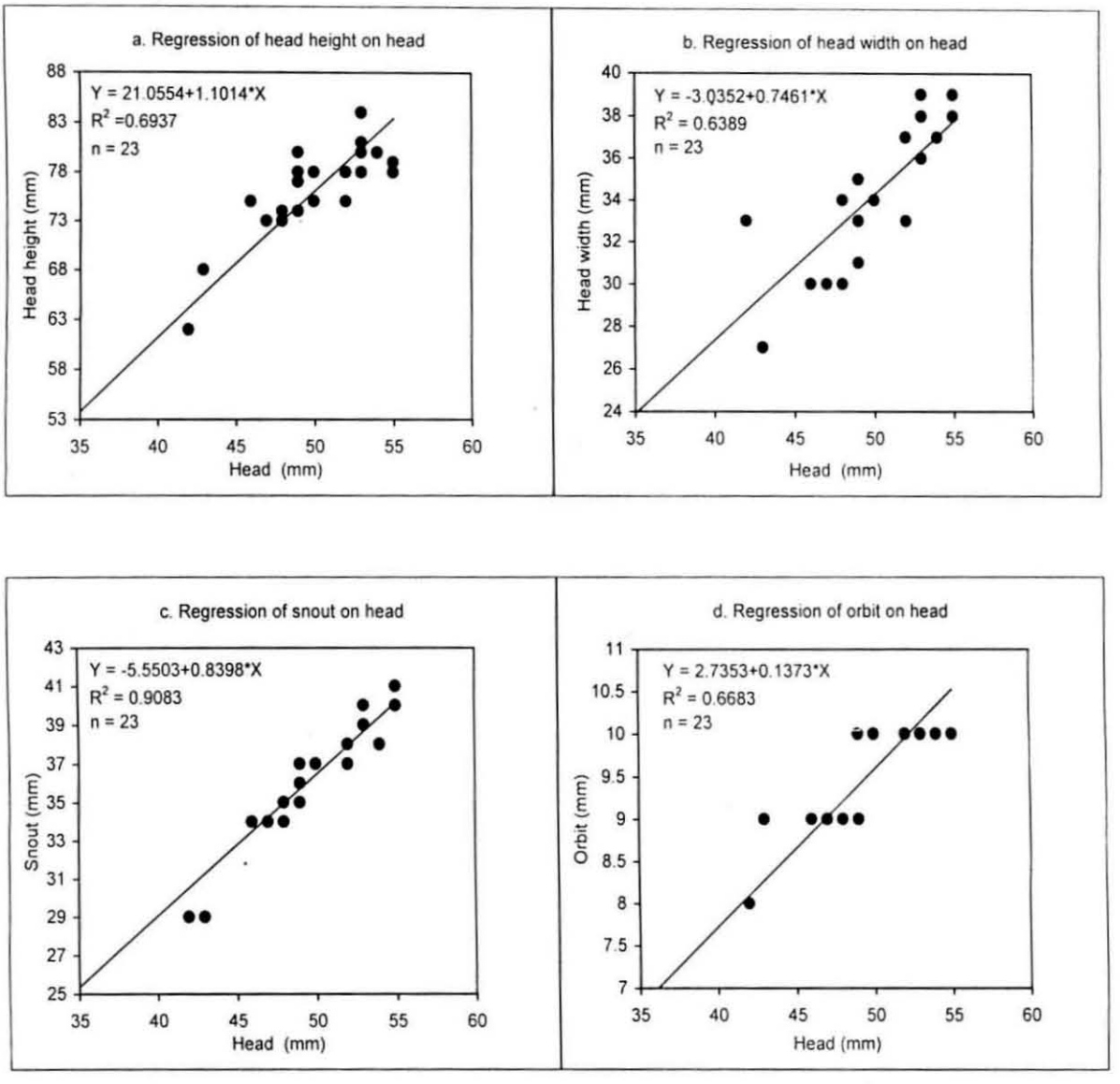


Figure 38. a-f. Regression of different head dimensions on head in *Melichthys indicus* from Minicoy Islands.

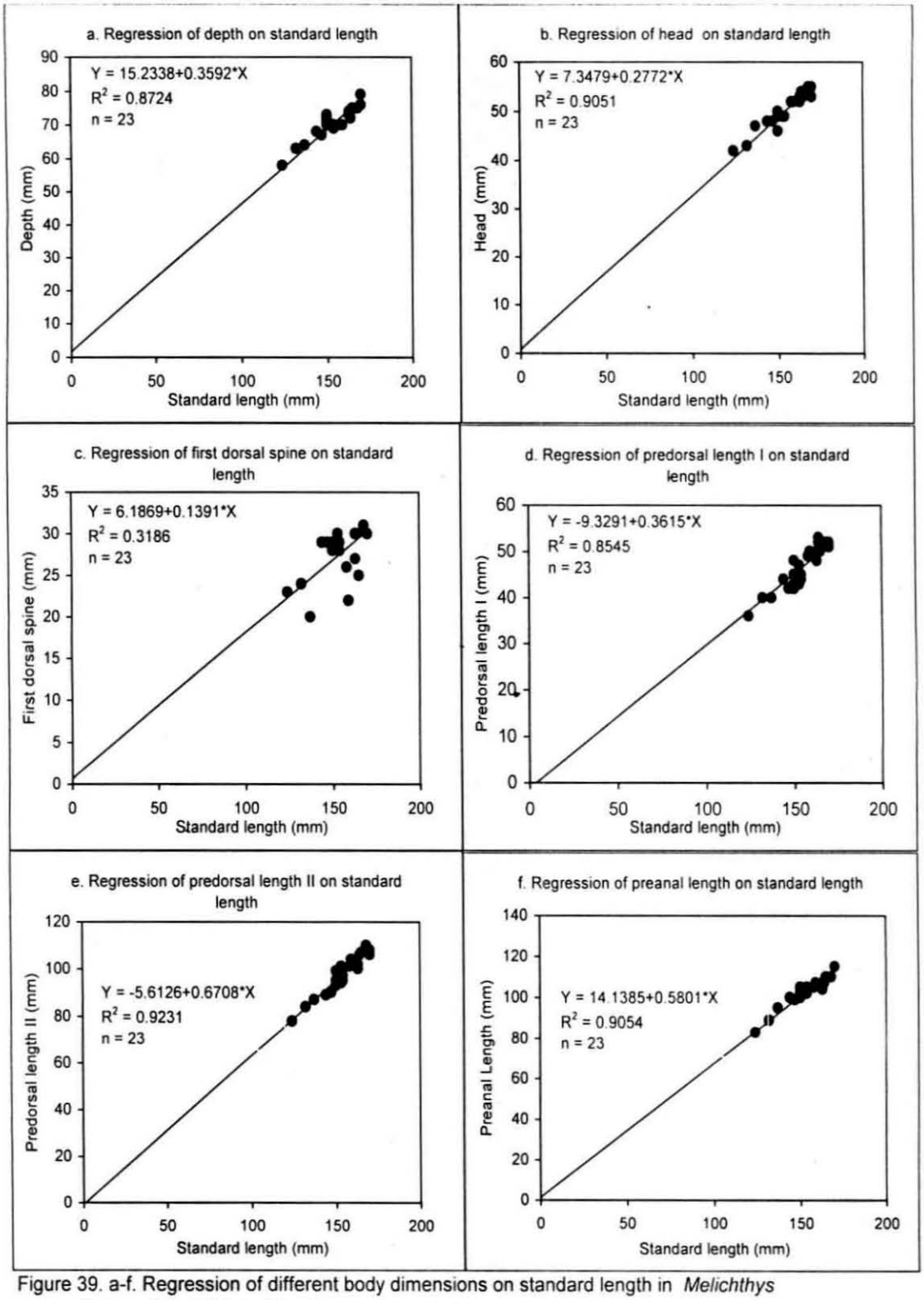


Figure 39. a-f. Regression of different body dimensions on standard length in *Melichthys indicus* from Minicoy Islands

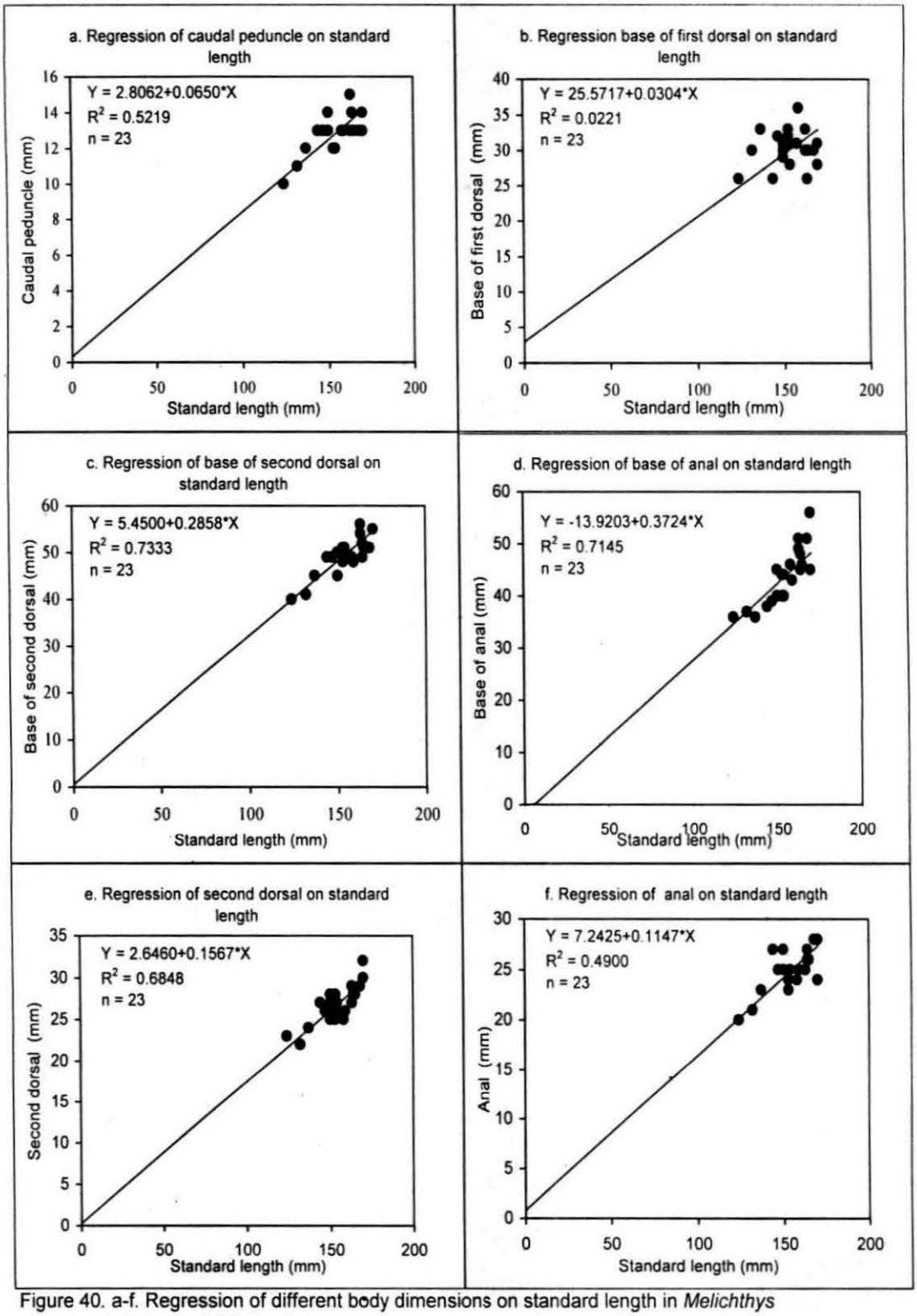
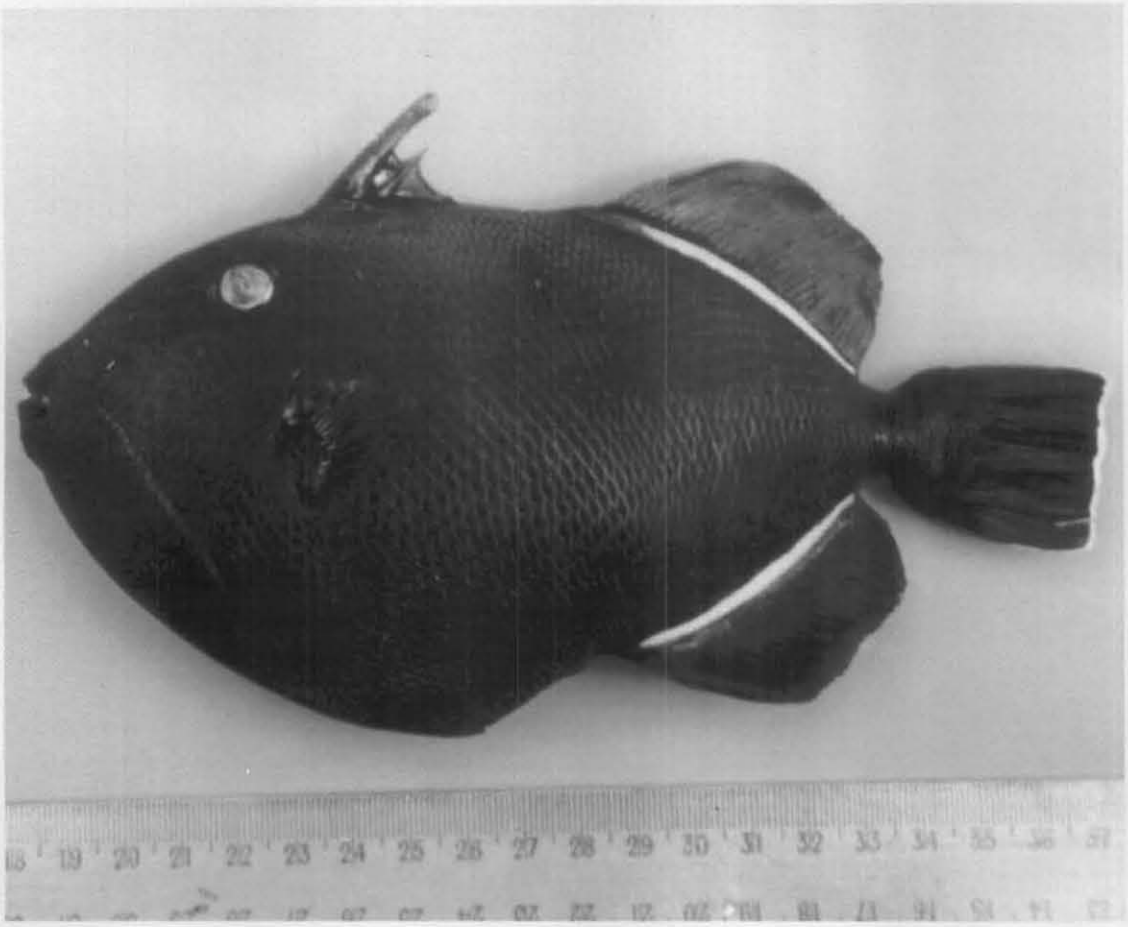
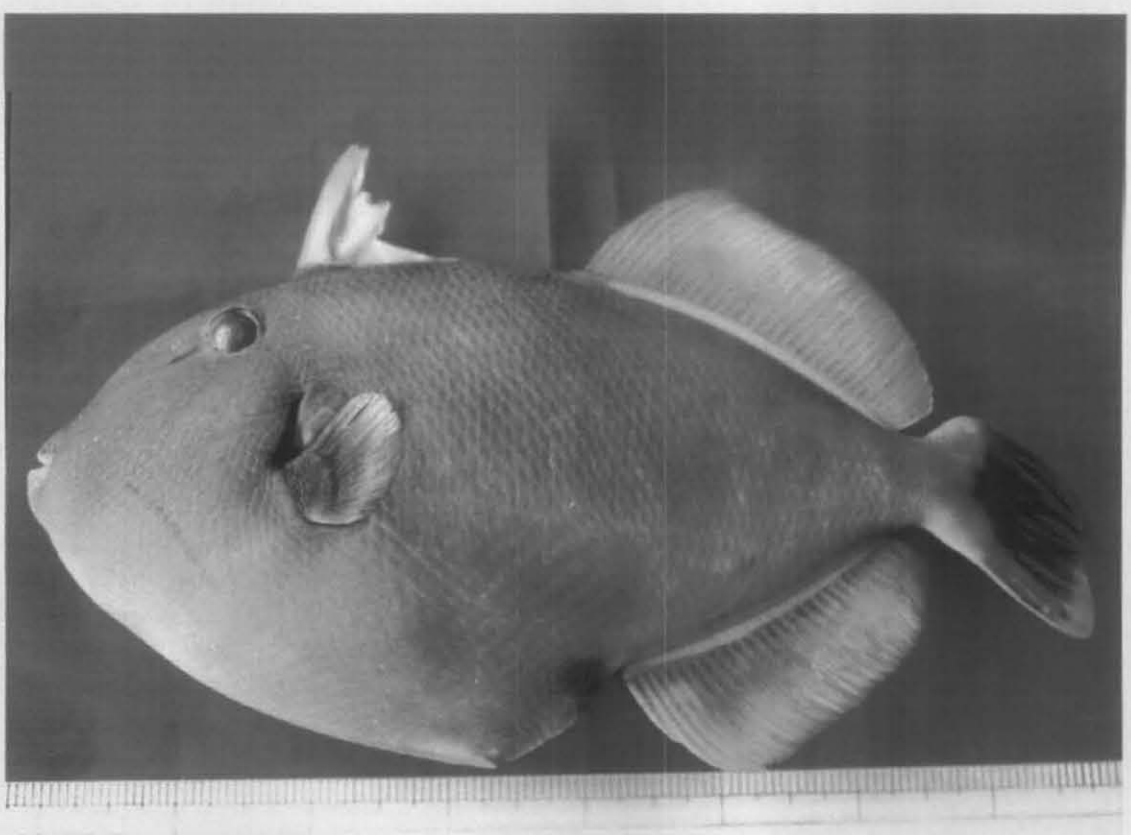


Figure 40. a-f. Regression of different body dimensions on standard length in *Melichthys indicus* from Minicoy Islands



A



B

Figure 41. *Melichthys indicus* Randall and Klausewitz, 1973: A. From MInicoy 182 mm TL, B. From Minicoy CMFRI Reg. No. 554 200 mm TL.

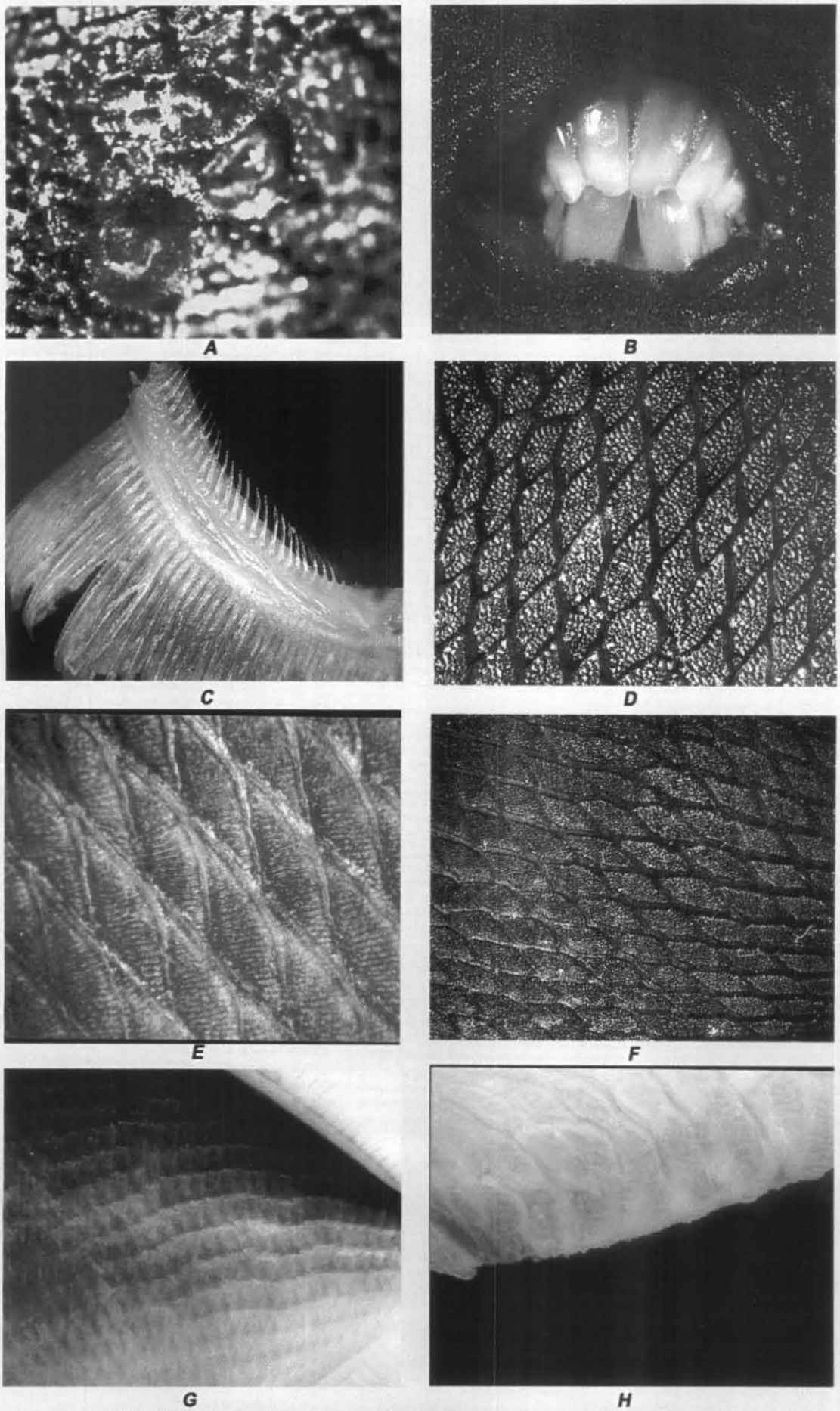


Figure 42. *Melichthys indicus* Randall and Klausewitz, 1973: A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on abdomen, G. Scales on caudal peduncle, H. Ventral spines.

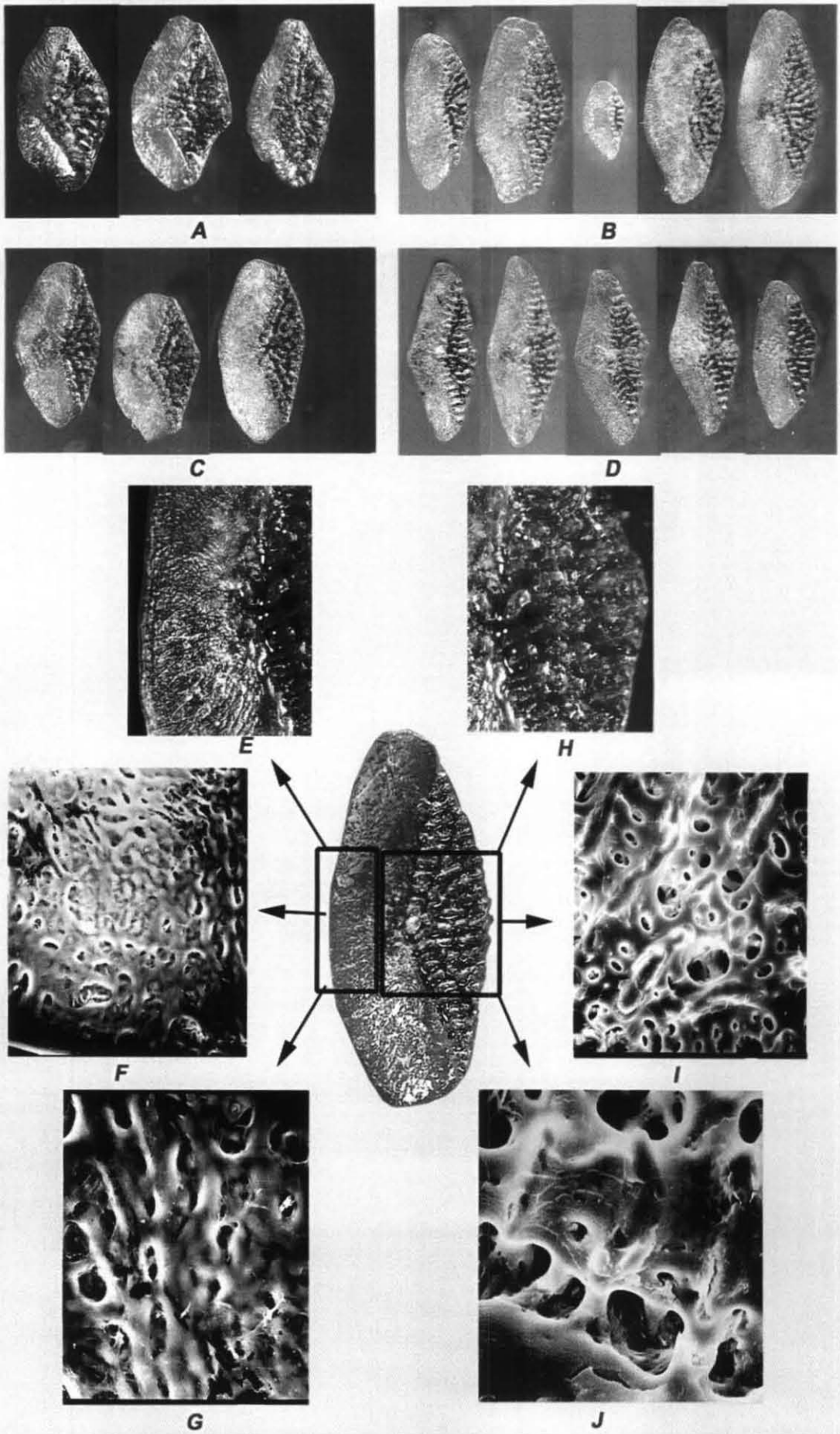
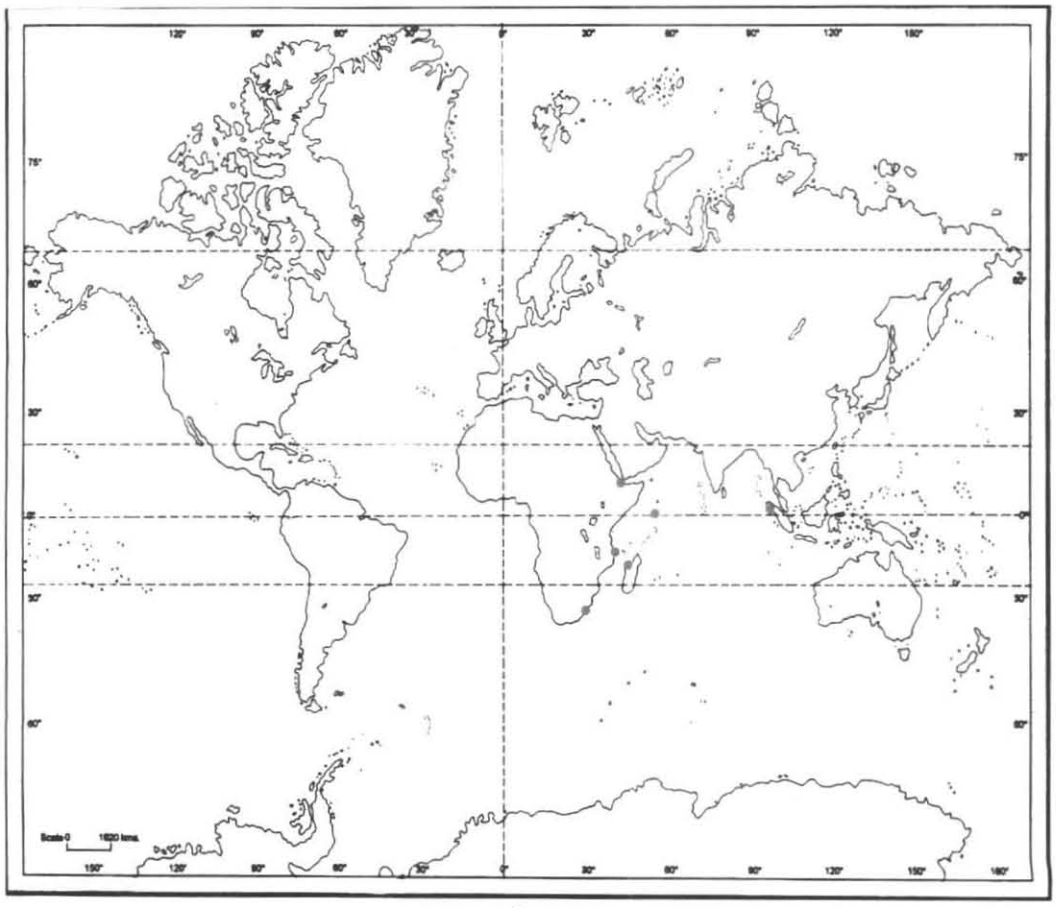
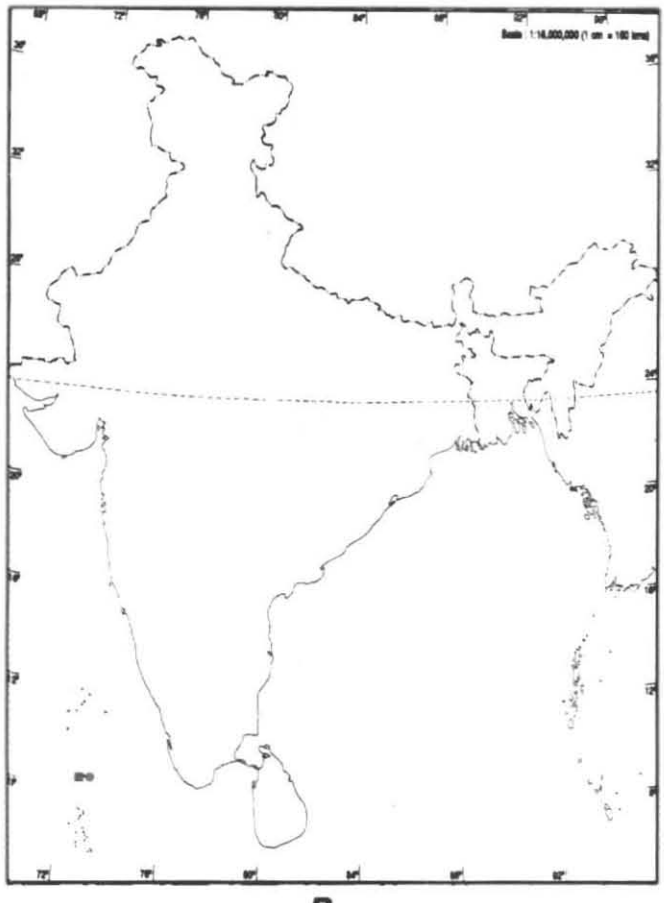


Figure 43. *Melichthys indicus* Randall and Klausewitz, 1973: A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x, 100x, 200x.



A



B

Figure 44. *Melichthys indicus* Randall and Klausewitz, 1973 : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.5. Genus *Canthidermis* Swainson, 1839

(Type species: - *Canthidermis oculatus* Gray, 1830.)

Diagnosis

Anterior nasal funnel shaped. Groove present. Scales on cheek square at the anterior, posteriorly rhomboid with some triangular scale in between arranged horizontally with fleshy row in between. Body scales with ridges and a large ridge at the anterior middle. Caudal peduncle, longer than deep, laterally elliptical, 8-10 rows of scales with blunt ridges at the centre, arranged horizontally. Ventral flap absent. Caudal double lunate.

2.5.5.1. *Canthidermis maculatus* (Bloch, 1786)

(Figure 48)

Balistes maculatus Bloch, 1786, p.25,pl. 151.
Balistes maculatus Day, 1878, p.687.
Canthidermis rotundatus Jones and Kumaran, 1980, p. 665, fig.566.

Material examined: 23 specimens from Vizhinjam, (12 females, 11 males) ranging from 220 to 369 mm TL.

Additional material examined: 1 specimen, from Bay of Bengal, ZSI. Reg. No. 11882, of length of 162 mm TL, (Fig.48.F), 2 specimens, from Madras coast, ZSI Reg. No. 13748, 13750, of lengths 113, 98 mm TL, (Fig.48.D & E) , 2 specimens, from Sand Head, ZSI Reg. No. 8164, 8165, of lengths 70 - 86 mm TL, (Fig. 48.C).

Description

D. III, ii, 21–26; P. i, 13 –14; ventral spines 0 –12; A. i, 18 –22; C. ii, 10; gill rakers 19-23; number of scales from origin of second dorsal to base of anal 16–20; lateral line scales 48 –70; scales round the caudal peduncle 11–15.

As percent of head: Head height 96.63–114.04 (105.47); head width 40.32–60.0 (53.38); orbit 17.65–21.95 (19.75); interorbital 37.08–45.61 (41.10); postorbital 16.92–24.19 (20.53). The regressions of different head dimensions on head are given in figure 45.

As percent of standard length: Depth 35.56–43.53 (39.10); head 30.51–34.83 (32.16); snout 18.01–20.63 (19.17); predorsal length (I) 26.79–33.71 (30.96); predorsal length (II) 59.05–64.25 (61.59); preanal length 62.0–67.20 (64.51); postdorsal length (I) 46.63–54.78 (50.83); post dorsal length (II) 8.11–15.27 (11.22); base of first dorsal 15.60–22.70 (18.63); base of second dorsal 22.52–34.39 (27.38); base of anal 20.26–29.10 (25.62); second dorsal 22.92–29.41 (25.98); anal 22.22–28.49 (25.33); pectoral 9.91–12.94 (10.78); caudal peduncle 10.69–12.70 (11.55). The regressions of different body dimensions on standard length are given in figure 46 & 47.

Body elongated. Head profile, convex, with a prominent chin. Lips broad at centre and narrows at edges. Interorbital convex. Groove equal to eye diameter, narrow and deep anteriorly and broad posteriorly, connected to nasal depression by narrow groove. First dorsal spine pointed, anteriorly with large spinules on tip, compressed and smooth laterally. Third spine ¼ the length of first spine. Nostrils placed in a shallow depression with blunt round protuberances bordering the depression (Fig. 49.A). The teeth of the upper jaw is rectangular with conical edge, the teeth of the lower jaw is rectangular with a conical upper side (Fig. 49.B).

Scales above the base of pectoral absent. The Gill rakers are short and do not project above the edge of the branchial arch, the tip is pointed (Fig. 49.C). Second dorsal and anal fins highly elevated anteriorly and short posteriorly. Pectoral fin rounded.

Scales on cheek have round protuberances and ridges arranged in vertical rows (Fig. 49.D & Fig. 50.A). Body scale with large ridge at the anterior middle (narrow posteriorly) and with many ridges and round protuberances. (Fig. 49.E & Fig. 50.B). The ultra structure of the anterior margin of the body scale shows round depressions and a

network of fibres (Fig. 50.E-G) and the posterior margin has blunt round protuberances (Fig. 50.H-J). Scales on abdomen rectangular to rhomboid shaped with many ridges and round protuberances arranged in 3-6 oblique rows (Fig. 49.F & Fig. 50.C). scales on caudal peduncle have ridge (tapering towards posterior and pointed) at the anterior middle and ridges and round protuberances arranged in horizontal rows (Fig. 49.G & Fig. 50.D).

Ventral flap is reduced. The ventral spines are modified into a single row of modified scales, present at the ventral side and each scale has many spines directed back wards giving a comb like appearance (Fig. 49.H). Pelvic spine is movable, short, flat, thick and blunt, with small, blunt minute protuberance.

Colour

The whole fish is dark brownish black. Three types of colour pattern was recorded in the specimens collected from Vizhinjam area,

1. Body brownish black with dash like white spots, which becomes round on the head and caudal area.
2. Body brownish black with white round spots, spread all over the body.
3. Body brownish black light brown ventrally.

Colour of the preserved specimens: Formalin preserved specimens have dark brown with white spots, in some cases it is without spots. Alcohol preserved specimens have light brown colour.

Distribution

West Indies (Bloch, 1786); America (Gmelin, 1789); Manila (Proce, 1822); New Guinea (Quoy and Gaimard, 1824); Bora-Bora, Society Islands (Lesson, 1830); India (Gray, 1831); Hawaiian Islands, Acapulco (Mexico) (Lay Bennett, 1839); Huacho (Peru) (Tschudi, 1845); Solor, New Guinea (Bleeker, 1853, 1859); Vanikoro, Santa Cruz Islands (Society Islands) (Hollard, 1854); Wood Lark Island (Thiolliere, 1857); Sidney (Kner,

1865); Darien (Cape, 1870). Jamaica, West Indies, Cape of Good Hope, Pinang, Borneo, Sandal Wood Island, India (Gunther, 1870); Darien (Cape, 1871); Madras (India) (Day, 1878); Misaki (Japan) (Snyder, 1912); East Indies, Ryukyu Island, Misaki, Sagami (Japan) (Jordan *et al.*, 1913); Manukan, Cagayan Islands, Sulu Sea (Herre, 1926); St. Augustine beach (Kritzler, 1951); Delaware, Bermuda, Argus Bank, Sea Brooks Beach, South Carolina, Gulf Stream, Silver Bay Station, Gulf of Mexico, Crandon Park Marina, Key Biscayne (Florida), Miami (Florida), Biscay Bay, Dade County (Florida), Bimini (Bahamas), Oregon Station, Atlantis, West Indies, Buenos Aries, Salina Cruz Bahia, Chipequa (Mexico) in Pacific between Guatemala and El Salvador (Donald Moore, 1967); Great Bahamas Bank (Gulf of Mexico) (Bohlke and Chaplin, 1968); Casurina Bay, Andaman (India) (Menon and Talwar, 1972); Okinawa Island, Ryukyu Island, Hokkaido, Kochi prefecture, Ogasawara Islands (Matsuura, 1980); Maldives (Jones *et al.*, 1981); Pacific Ocean, Indian Ocean (Fedoryako, 1981); Thailand (Nateewathana *et al.*, 1993); Yenliu (Taiwan) (Shao *et al.*, 1994); Miyanohama beach (South of Japan) (Matsuura *et al.*, 1994) (Fig. 51A & B).

Taxonomic note

According to Fedoryako (1981) in Pacific and Indian oceans there are 5 species of *Canthidermis, viz., C. willughbeii* (Lay and Bennet, 1839), *C. maculatus* (Bloch, 1786), *C. rotundatus* (Proce, 1822), *C. sufflamen* (Mitchill, 1815), and a fifth species *C. villosus (new)* collected from Gulf of Aden.

Fedoryako (1981) observed that *C. villosus* and *C. rotundatus* have same number of fin rays, number of gill rakers and armature of trunk scales. He indicated the differences as, presence of branched dermal protuberances on scales, relatively smaller number of transverse rows of trunk scales, different length/depth ratio of the caudal peduncle and colouration of body and fins.

In case of *C. maculatus*, the author has mentioned that the number of rays of second dorsal and anal fins differs slightly in the limits of variability and these fins are shorter compared to Moore (1967) description. It differs from *C. rotundatus* and *C. villosus* due to smaller number of fin rays and gill rakers, a greater number of small spinules on the trunk scales mottled body colouration.

C. rotundatus is different from *C. maculatus* because of difference in scale armature on the trunk, number of fin rays and gill rakers while longer specimens of *C. rotundatus* and *C. maculatus*, has a longer second dorsal fin, a taller anal, pre-anal distance was less in former. But *C. rotundatus* was similar to *C. villosus* and *C. sufflamen* except that the latter has a greater number of transverse rows of scales, body depth and height of second dorsal and anal fins in comparison to *C. maculatus*. The fin ray counts of all the species are given in the table 4.

Table 4. The fin ray counts of different species of *Canthidermis*

	Second dorsal	Anal	Pectoral	Standard length (mm)
C. maculatus	23-26	21-23	13-15	50-100
C. willughbeii	23-24	21-22	13-14	90-131
C. rotundatus	25-27	22-23	14-16	39-111
*C. **villosus***	24-26	22-23	14-15	71.7-177.7
C. sufflamen	23-25	20-22	13-15	20-300(Moore, 1967)

Berry and Baldwin (1966) observed that,

> "The synonym of this species has been confused because identifications and names based on small specimens (as "*rotundatus*" Proce and "*oculatus*" Gray) have not been recognized as co specific with larger, more elongate specimens (as "*maculatus*" Bloch, w*illughbei*i, Lay and Bennet and "*longirostris*" Tortonese). As the body length increases there is a proportional decrease in head length, eye diameter, body depth and first dorsal spine length and a proportional increase in length of the lobes of the anal and caudal fins".

1. From the above table it can be observed that the fin counts of *C. maculatus*, *C. willughbeii*, *C. rotundatus* and *C. villosus* falls within a narrow range and cannot be used for differentiating between species.
2. Fedoryako collection consists of narrow length range, having length ranges of 50-177.7 mm, except for *C. maculatus*, represented by a large sample, but smaller length groups.
3. Berry and Baldwin (1966) and Matsuura (1981) observed that, the three species of Swainson (1839) i.e. *Canthidermis angulosus* (Quoy and Gaimard, 1824), *Canthidermis gaimardii* (Swainson, 1839) and *Canthidermis oculatus* (Gray, 1831) are synonyms to *Canthidermis maculatus* (Bloch, 1786). They also established that *Balistes maculatus* (Gmelin, 1879) and *Balistes aureolus* (Richardson, 1845) of Gunther (1870) is also a synonym of *Balistes maculatus* (Bloch, 1786).
4. Some observations made on *Canthidermis maculatus* collected from west coast of India and Minicoy islands showed that 3 different colour patterns exist, i) uniform brownish black dorsally and light brown ventrally, ii) uniform brownish black with round white spots well distributed on the body, iii) brownish black body with white longitudinal dashes distributed on the body. The regression graphs drawn using data of various morphometric measurements on standard lengths revealed low relationship, suggesting that *Canthidermis maculatus* has high degree of variability in case of body colour and certain morphological characters.
5. Thus it is concluded that, *C. willughbeii* (Lay and Bennet, 1839), *C. rotundatus* (Proce, 1822), *C. villosus* Fedoryako, 1981 are junior synonym of *C. maculatus* (Bloch, 1786).

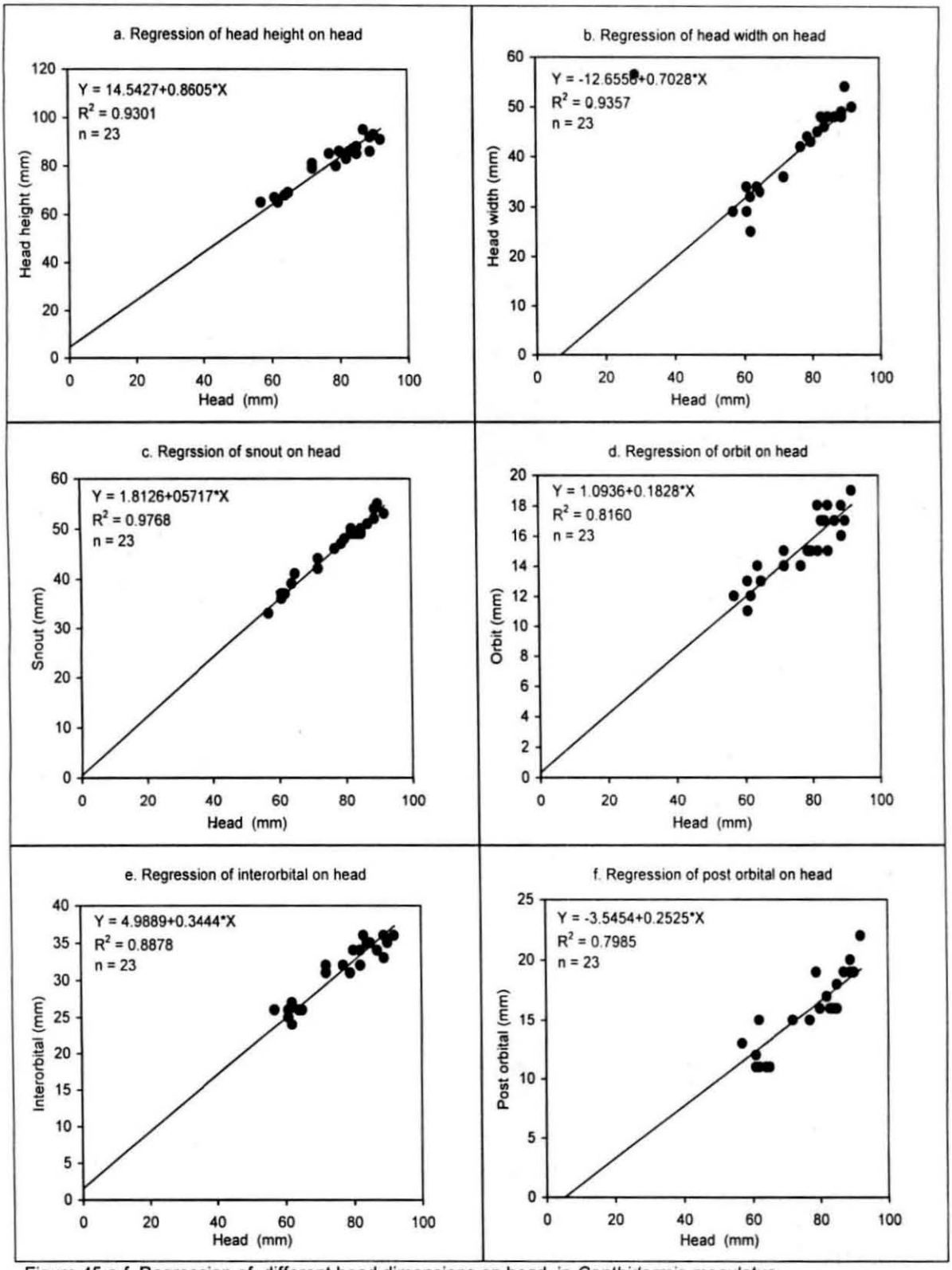


Figure 45.a-f. Regression of different head dimensions on head in *Canthidermis maculatus* from south west coast of India.

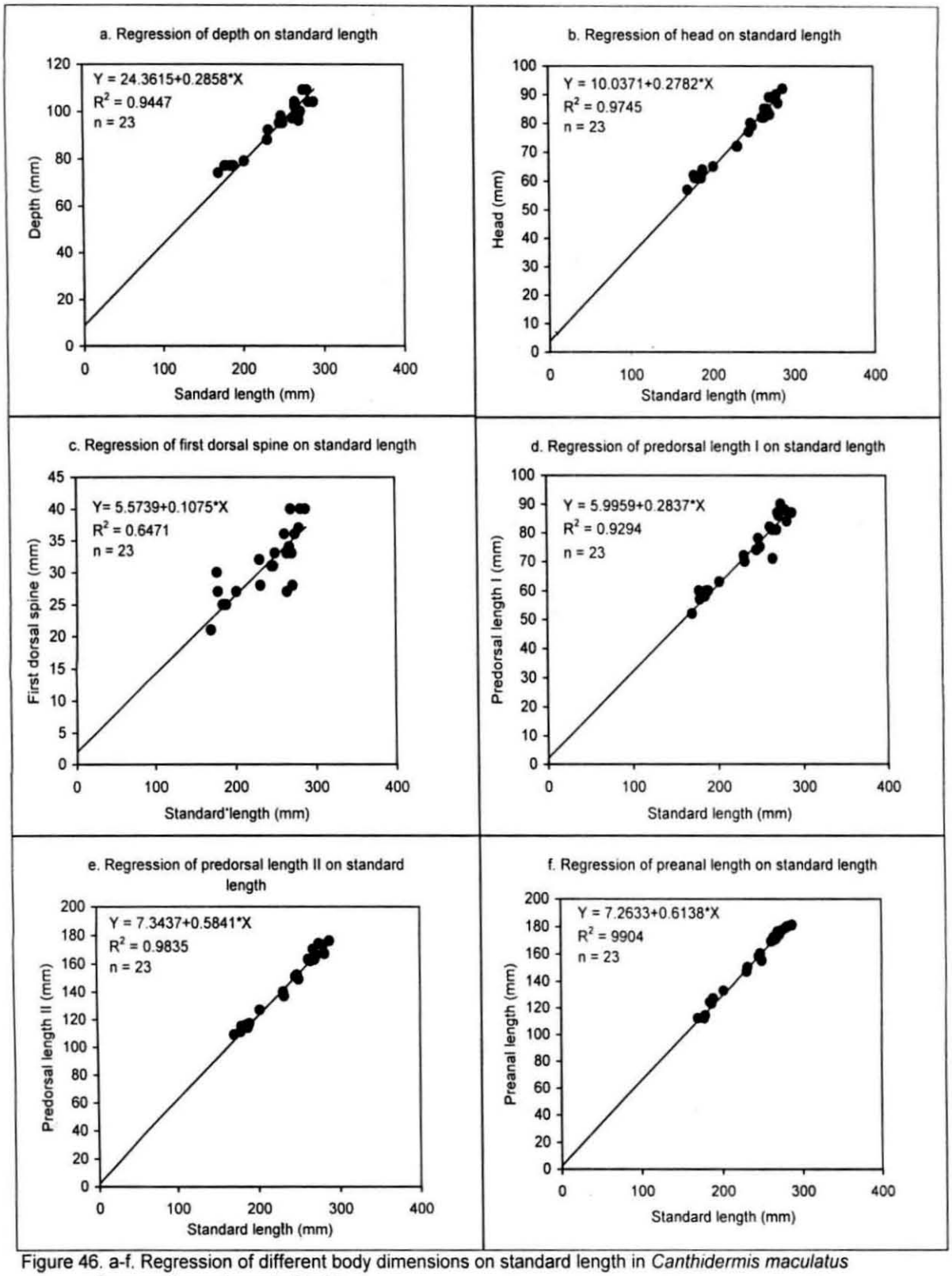


Figure 46. a-f. Regression of different body dimensions on standard length in *Canthidermis maculatus* from south west coast of India

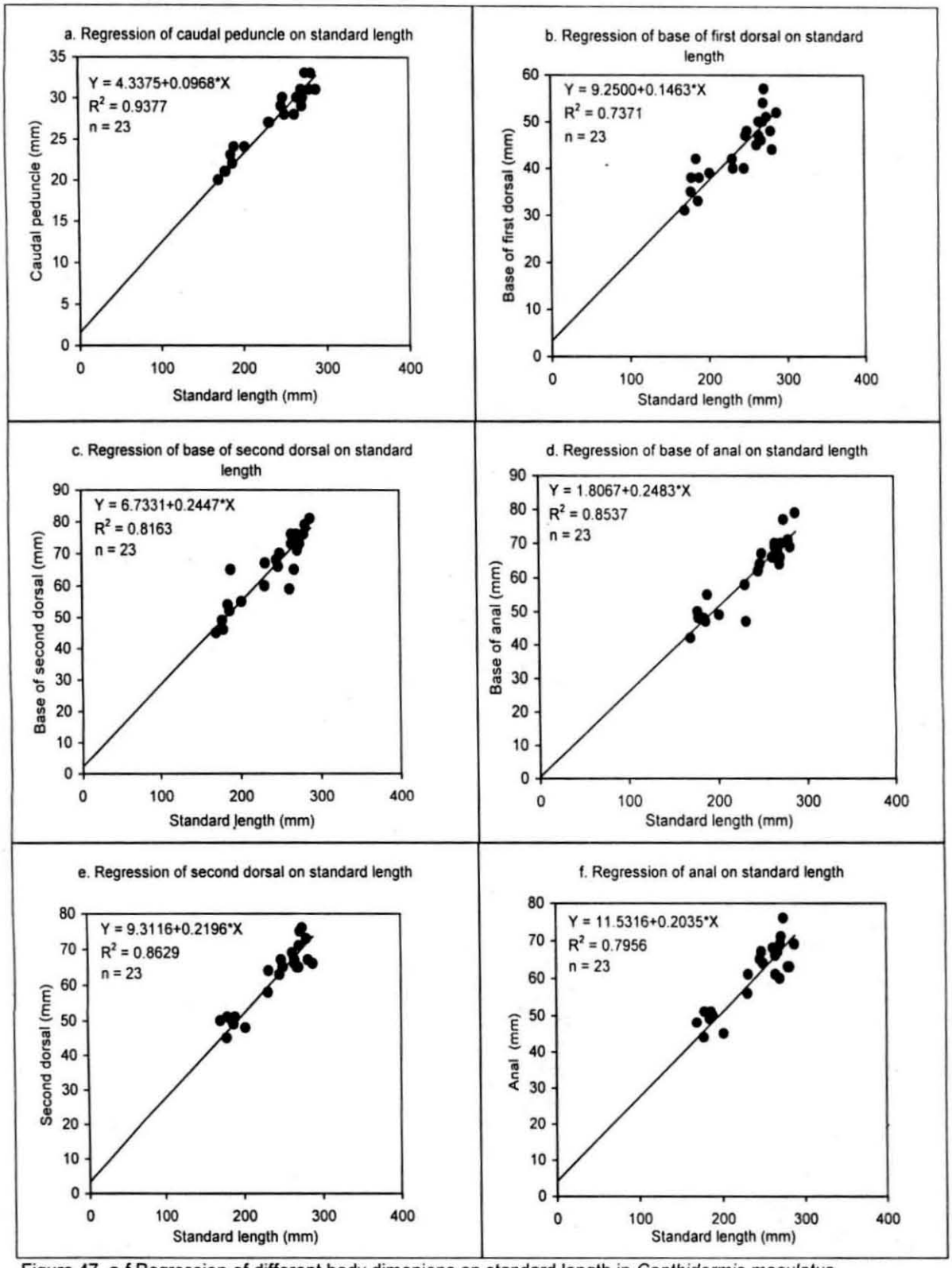


Figure 47. a-f.Regression of different body dimenions on standard length in *Canthidermis maculatus* from south west coast of India

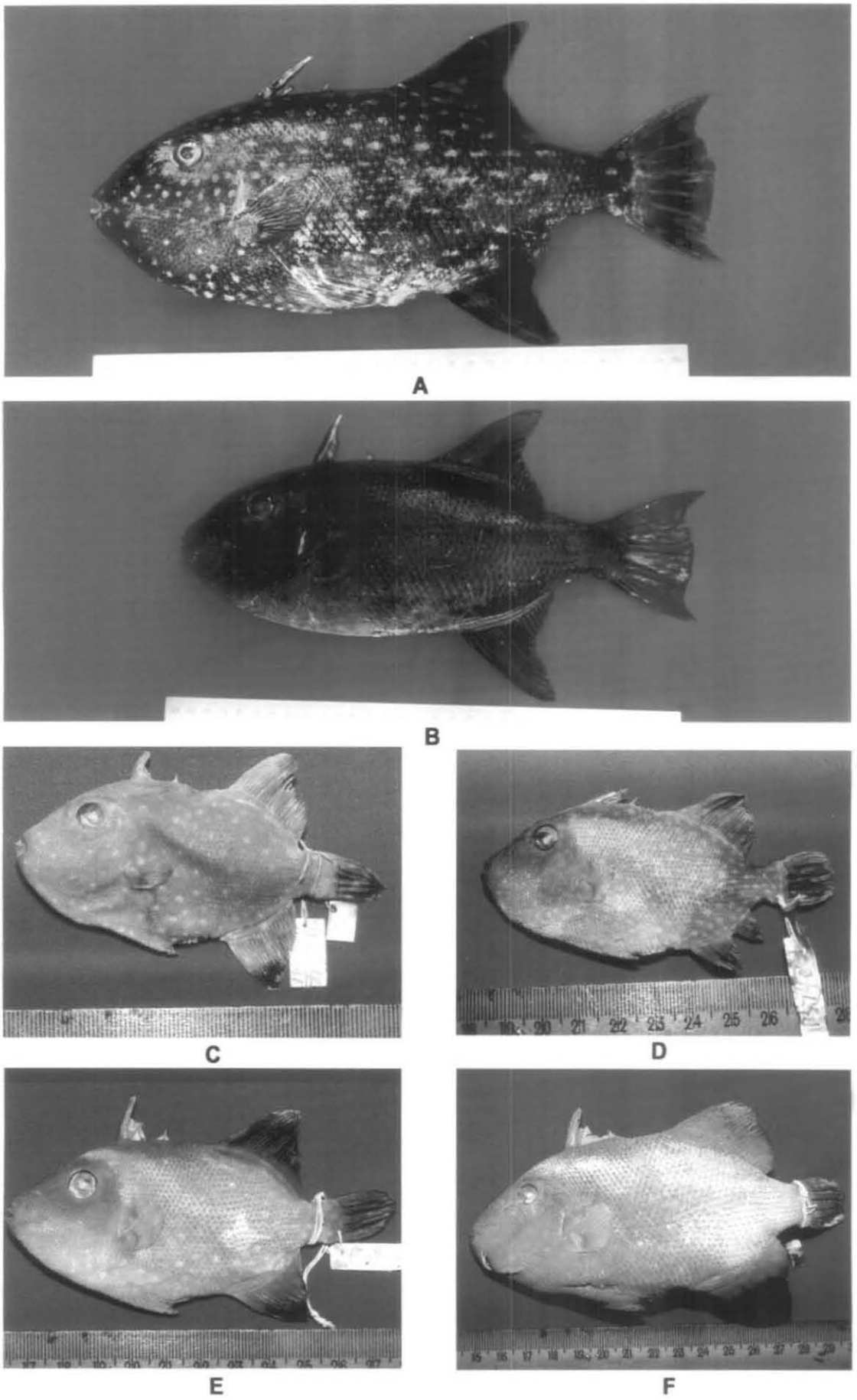


Figure 48. *Canthidermis maculatus* (Bloch, 1786) : A. From Vizhinjam, 336 mm TL, B. From Vizhinjam 317 mm TL, C. From Sand Head ZSI Reg. No. 8165, 86 mm TL, D. From Madras ZSI Reg. No. 13748, 98 mm TL, E. From Madras ZSI Reg. No. 13750, 113 mm TL, F. From Bay of bengal ZSI Reg. No. 11882, 163 mm TL.

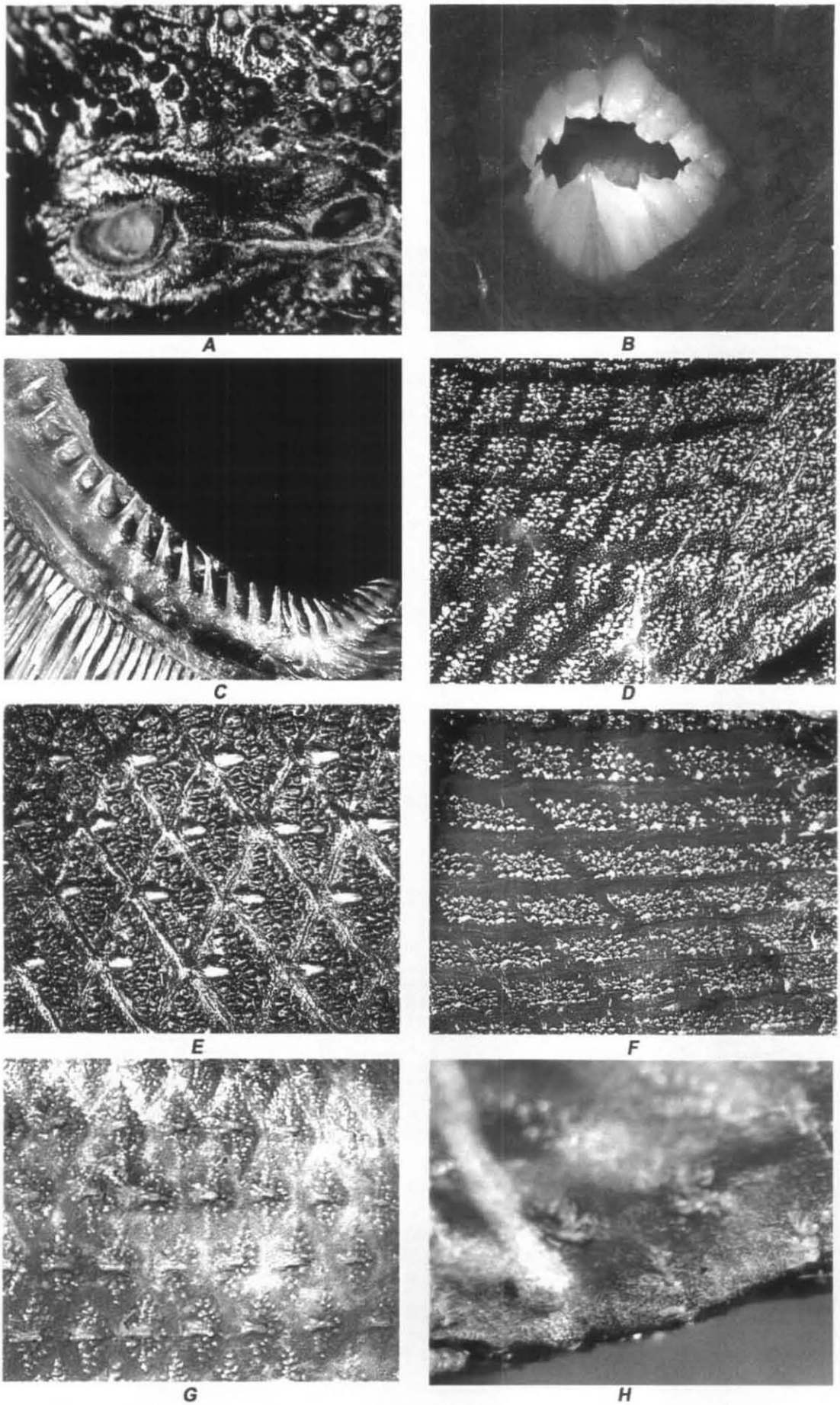


Figure 49. *Canthidermis maculatus* (Bloch, 1786): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

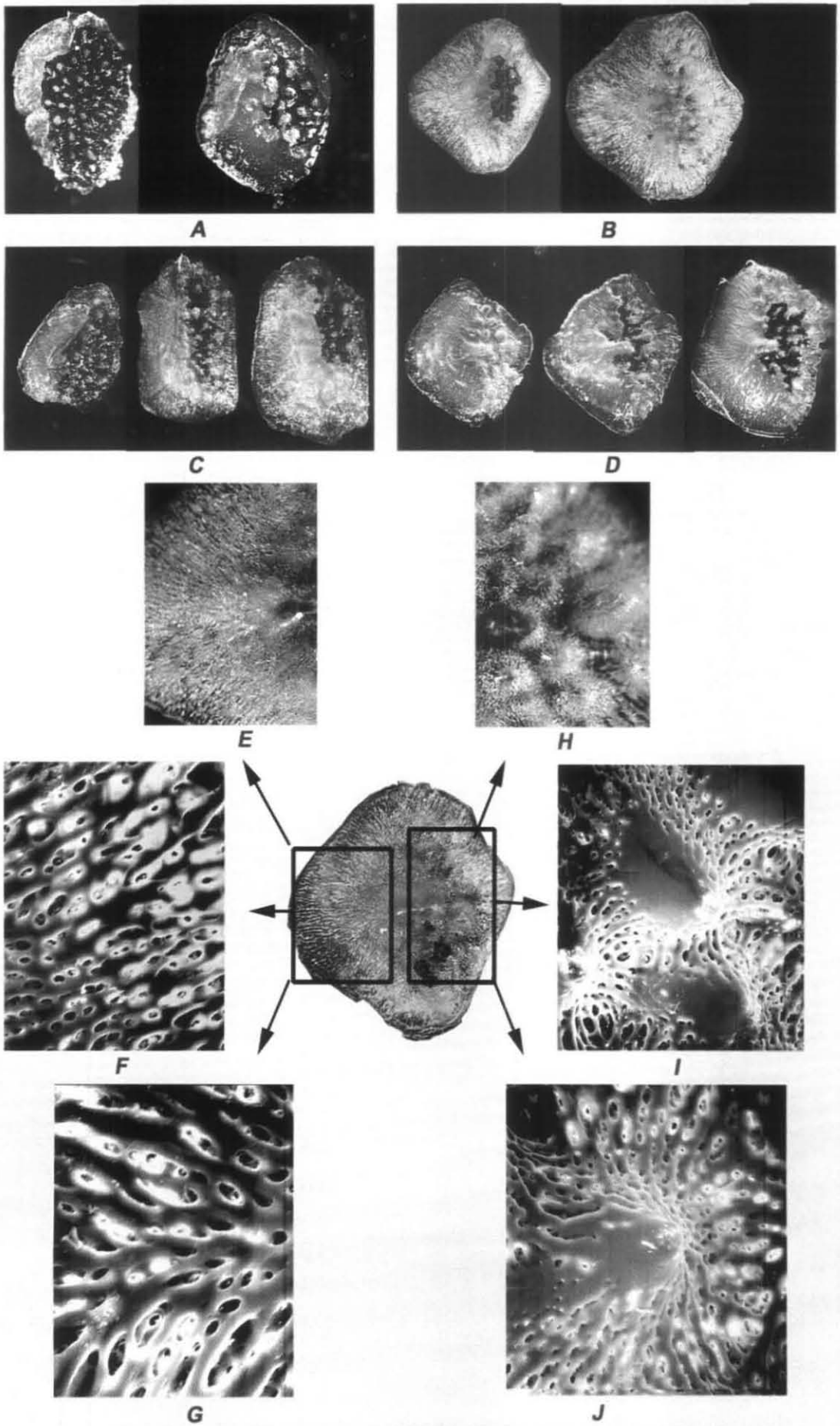
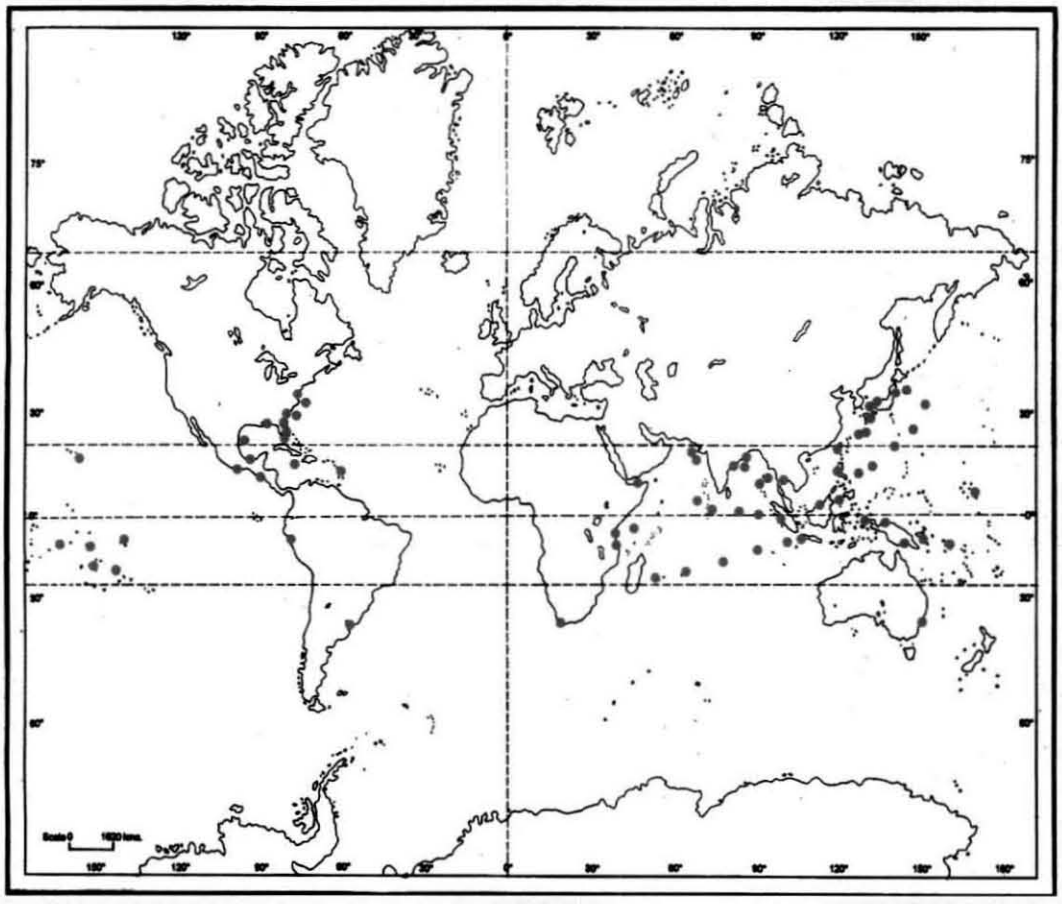
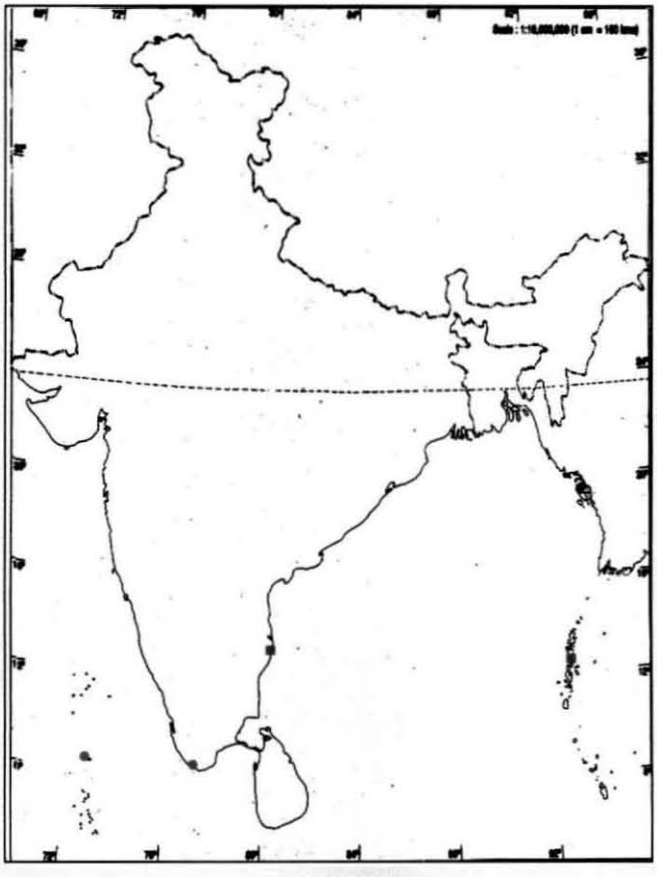


Figure 50. *Canthidermis maculatus* (Bloch, 1786) : A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.



A



B

Figure 51. *Canthidermis maculatus* (Bloch, 1786) : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.6. Genus *Parabalistes* Bleeker, 1866

(Type species *Parabalistes chrysospilus* Bleeker, 1866 = *Balistes chrysospilus* Bleeker, 1853.)

Diagnosis

The anterior nostril ridge-like, with a circular opening at the top. Groove before eye. Scales on cheek absent anteriorly, posteriorly transverse rows of square scales are present with wide fleshy rows in between. Body scales have spherical protuberances. Caudal peduncle is short and deep, with round protuberances, arranged horizontally. Caudal truncate with filamentous rays on the upper and lower lobes.

The subgenus *Parabalistes* was erected by Bleeker (1866) with the following characters, 1) head profile obtuse, convex. 2) Rostrum naked, scales arranged in rows with some longitudinal gaps in between on the cheek. 3) Longitudinally 45 scales. 4) Caudal peduncle without spines. 5) Second dorsal and anal elevated anteriorly and angulated, caudal rounded with marginal lobes produced.

Herre (1924) mentioned that this genus is not distinctive enough to be considered as a separate genus in the family Balistidae and included *fuscus* in the genus *Balistes*.

Fraser – Brunner (1935) and Matsuura (1980) treated this subgenus as a synonym of genus *Pseudobalistes*.

Characters like i) scales on cheek are horizontally arranged, with shallow fleshy groove in between, ii) the soft dorsal and anal are elevated anteriorly and angulated, iii) caudal peduncle without spines, iv) caudal truncate with filamentous rays in the upper and lower lobes, make this genus very distinct from the other genera of family Balistidae.

Balistes fuscus of Bloch and Schneider (1801) and *Parabalistes chrysospilus* of Bleeker (1866) are synonym (Herre, 1924).

The specimen recorded from the Lakshadweep archipelago and another specimen at the CMFRI museum, collected from south west coast of India conforms to the species description *Balistes fuscus* of Bloch and Schneider (1801) and *Parabalistes*

chrysospilus of Bleeker (1866). Some of the distinctive characters of these specimens are used for redefining the genus as:

> " Anterior nostril ridge-like, with a circular opening at the top. Groove before eye. Scales on cheek absent anteriorly, posteriorly transverse rows of square scales are present with wide fleshy rows. Body scales diamond shaped, having spherical protuberances. Caudal peduncle is short and deep with diamond shaped scales arranged in horizontal rows, with round protuberances. Caudal truncate with filamentous rays on upper and lower lobes."

Thus *Parabalistes* is a valid genus and monotypic.

2.5.6.1. *Parabalistes fuscus* (Bloch and Schneider, 1801)

(Figure 52)

Balistes fuscus Bloch and Schneider, 1801, p.471.
Balistes fuscus Day, 1878,p.690.

Material examined: One specimen from Agatti, (male) 145mm TL (Fig.52.A).

Additional material examined: One specimen from south west coast of India, CMFRI Reg. No. 1025, 362mm TL (Fig.52.B).

Description

D. III, i, 25; P. i, 12; Ventral spines 11; A. i, 22; C. ii, 10; number of scales from origin of second dorsal to base of anal 22; Lateral line scales 51; round the caudal peduncle 15.

As percent of head: Head height 125; head width 70.45; orbit 25; interorbital 27.27; postorbital 6.82.

As percent of standard length: Depth 53.04; head 38.26; snout 28.70; predorsal length (I) 35.65; predorsal length (II) 66.09; preanal length 69.57; post dorsal length (I) 39.13; post dorsal length (II) 6.96; base of first dorsal 25.22; base of second dorsal 26.96; base

of anal 26.09; second dorsal 22.61; anal 17.39; pectoral fin length 13.04; caudal peduncle 10.43.

Body oval, deep. Head profile convex, chin prominent. Lips, thick, fleshy, broad, and continuous at corner. Interorbital straight. Groove, shallow, equal to orbit, directed downwards. First dorsal spine, long, stout, tip pointed. Laterally compressed smooth. Third spine ¼ the length of first spine. Nostrils placed in depression, with a thin translucent "C" shaped flap on the anterior opening (Fig.53.A). The first teeth of the upper jaw conical with the tip pointed and diverging outside. The first teeth of the lower jaw conical with pointed tip. The other teeth are rectangular with conical upper edge (Fig. 53.B).

Few large and small-scale form a cluster, arranged on a depressed rectangular area above the base of pectoral. Gill opening vertical. The anterior rays of the second dorsal fin and anal fin are long and the posterior rays shortest thus making the fin elevated anteriorly and short posteriorly, fin profile concave. Pectoral fin rounded.

Scales on cheek are of two type i) scales with round protuberances and ridges arranged in 1- 4 vertical rows ii) scales of the fleshy rows (covered by skin) have shallow depressions and ridges and smooth surface (Fig.53.C). Body scales with vertical rows of spherical protuberances arranged in 5 - 10 vertical rows, with the anterior most row having the larger protuberances (Fig.53.D). Scales on abdomen rhomboid which are arranged in oblique rows, each scale has ridges on the first row and round protuberances in 3-5 oblique rows (Fig. 53.E). Scales on caudal peduncle have short round blunt protuberances arranged in 3-5 vertical rows (Fig.53.F).

Ventral flap, narrow, supported by hyaline spines (Fig.53.G). Rudimentary pelvic spine movable with many pointed and blunt glassy protuberances.

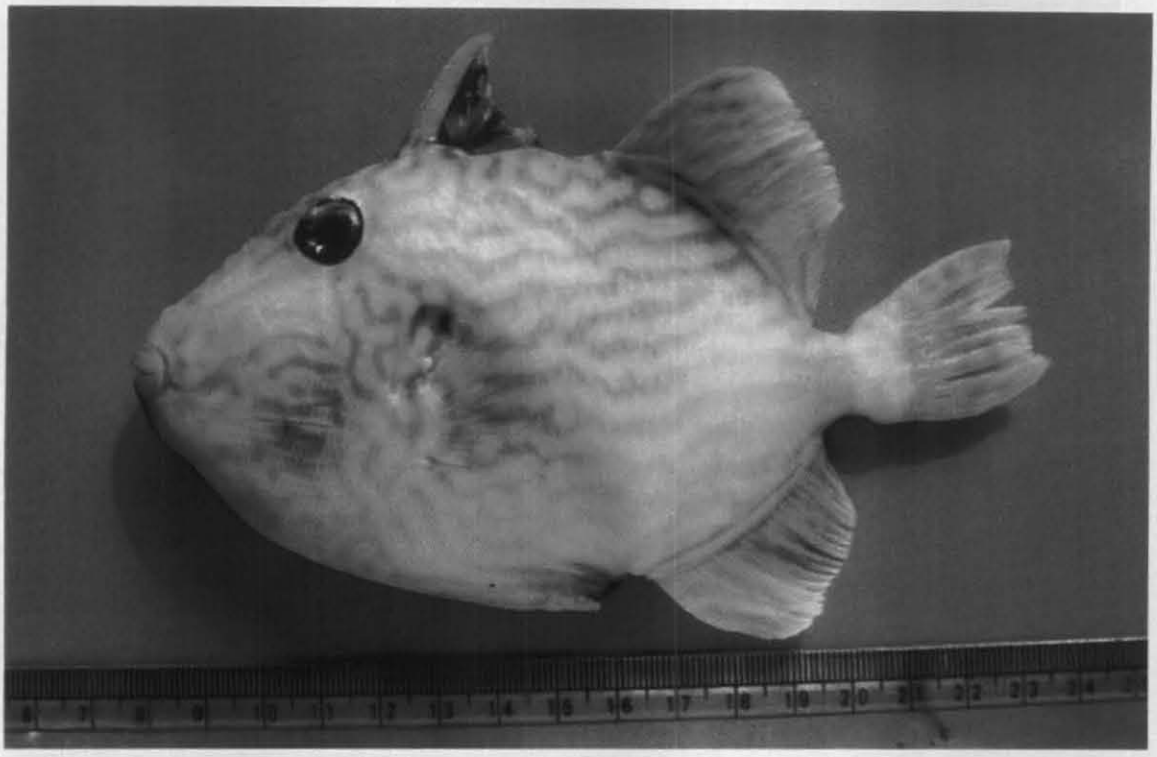
Colour

Formalin preserved fish whitish-brown, with horizontal wavy or undulating brown bands. First dorsal fin brown. Second dorsal anal fin whitish-brown with undulating brown bands. Caudal fin whitish-brown with brown vertical bands, pectoral translucent. Lips white.

Distribution

Red sea (Ruppell, 1820); Solor (Bleeker, 1865); Red sea, Zanzibar, Mauritius (Gunther, 1870); Kandavu (Fiji Island) (Gunther, 1876); Ceylon (Day, 1878); Tahiti (Seale, 1906); Fiji Ponape, Caroline Islands, Gilbert Islands, Society Islands (Gunther, 1910); Tatayan Island, Southern coast, Cotabato province, Mindanao (Herre, 1924). Tahiti (Seale, 1906); Misaki (Japan) (Snyder, 1912); New Guinea (Ducker and Mohr, 1929); Rongelap Atoll (Marshall Islands) (Schultz, 1966); Okinawa Island, Ryukyu Island, Ishigaki Island (Japan) (Matsuura, 1980); Sesoko Island (Japan) (Kuwamura, 1991) (Fig. 54.A & B).

Remarks: This species was recorded from Agatti Island for the first time (Lakshadweep archipelago).



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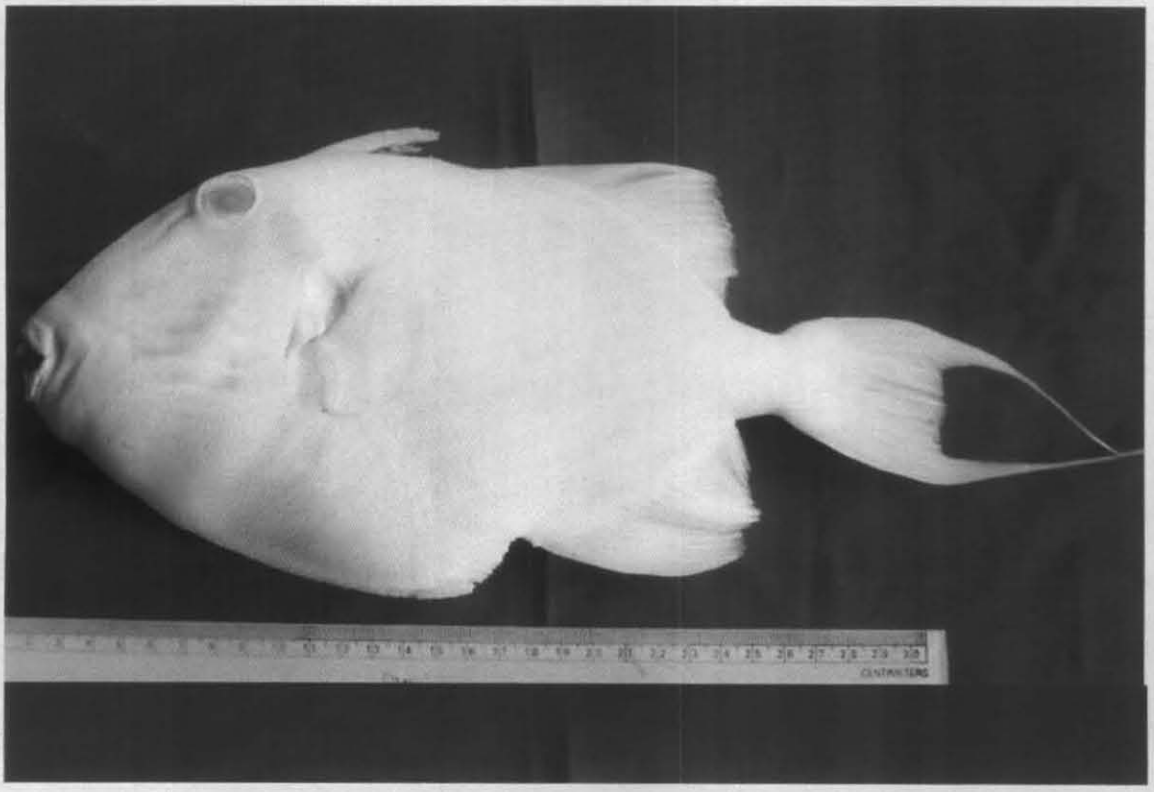


B

Figure 52. *Parabalistes fuscus* (Bloch and Schneider, 1801) : A. From Agatti, 145 mm TL, B. From south west coast of India CMFRI Reg. No. 1025, 362 mm TL.

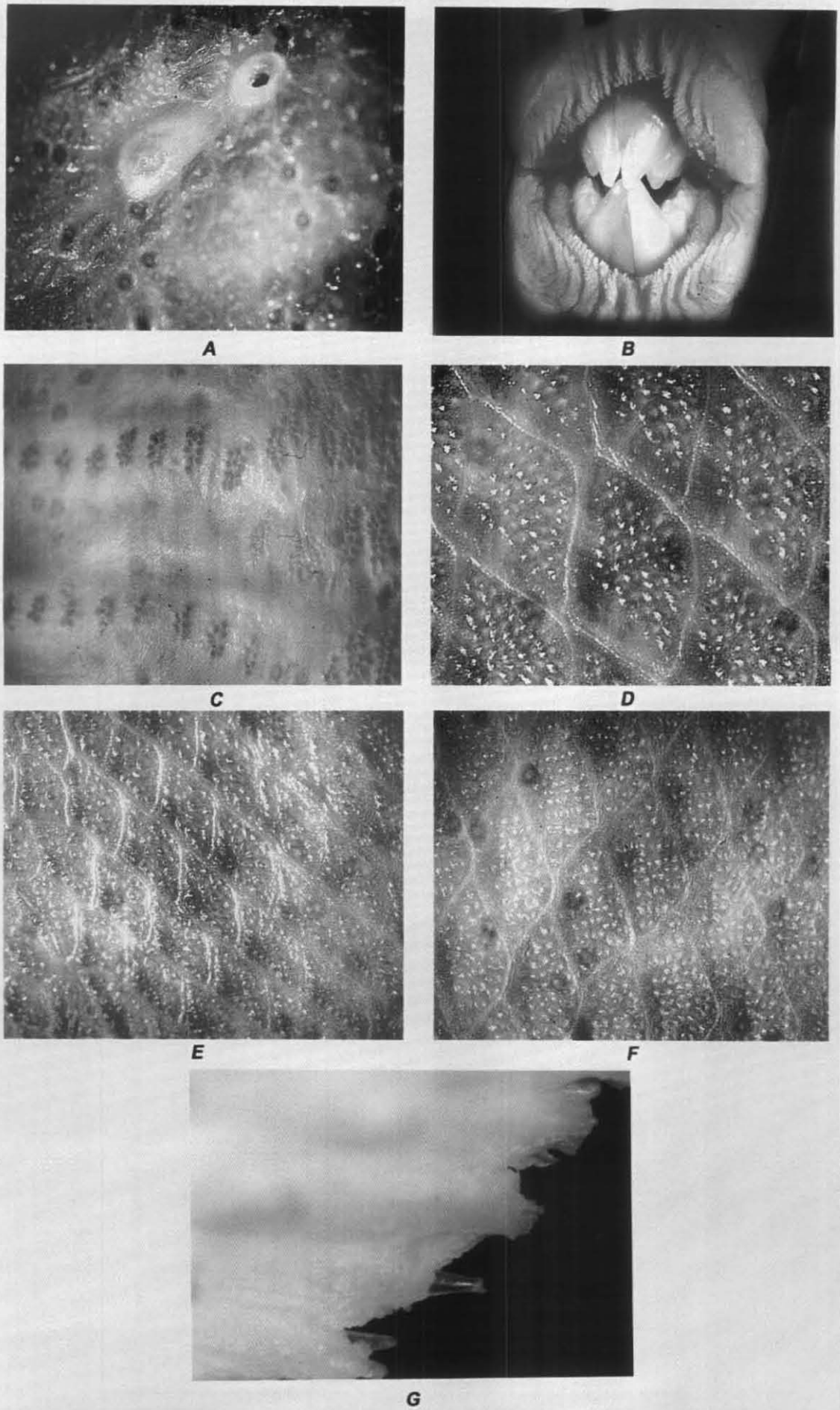
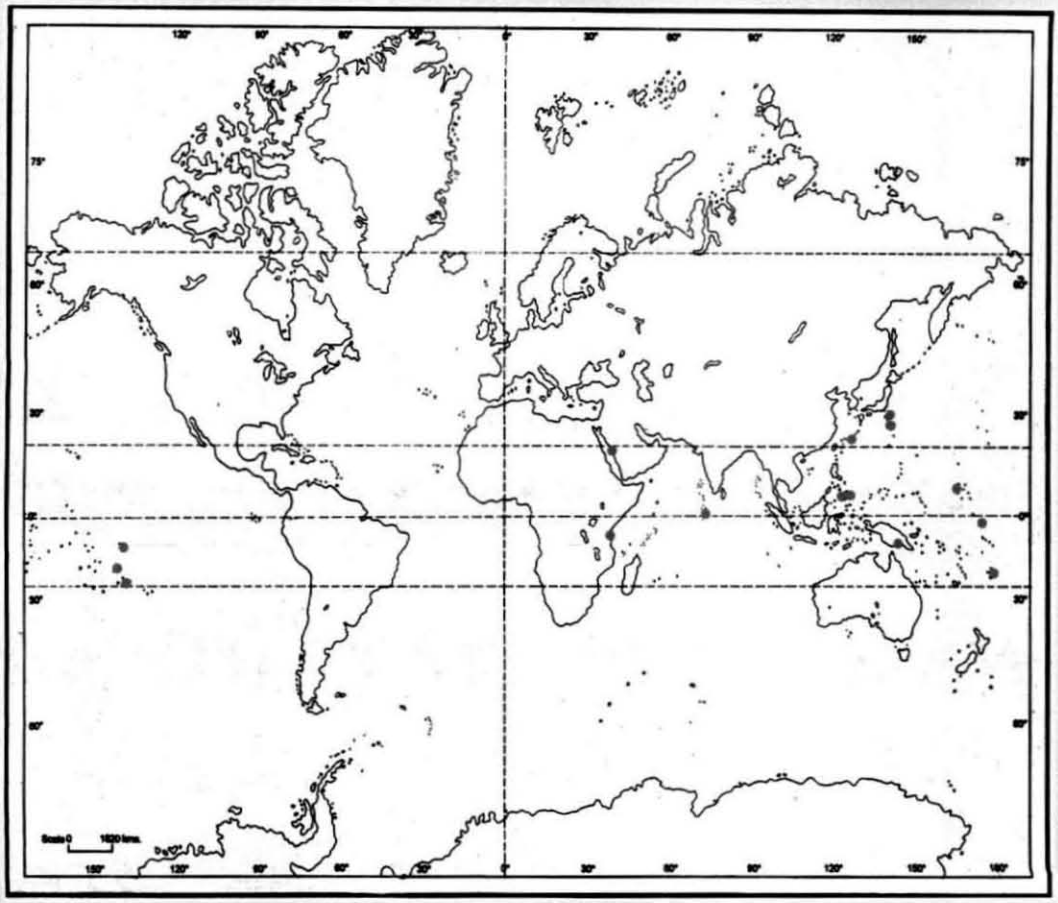


Figure 53. *Parabalistes fuscus* (Bloch and Schneider, 1801): A. Nasal apertures, B. Teeth, C. Scales on cheek, D. Body scales, E. Scales on Abdomen, F. Scales on caudal peduncle, G. Ventral spines.



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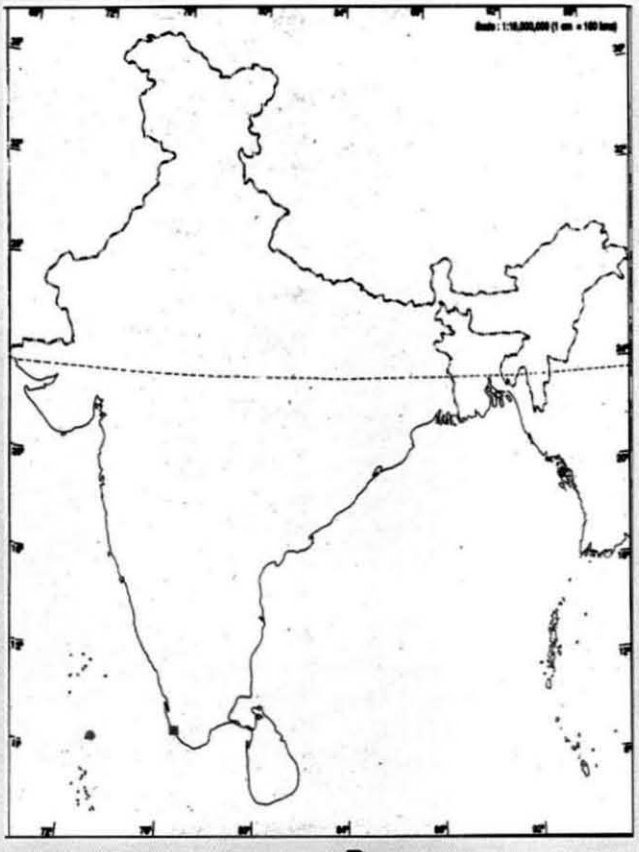


B

Figure 54. *Parabalistes fuscus* (Bloch and Schneider, 1801) : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.7. *Pseudobalistes* Bleeker, 1866

(Type species *Pseudobalistes viridescens* Bleeker, 1866 = *Baliste verdatre* Lacepede, 1798)

Balistoides Fraser-Brunner, 1935, p.662.
Type species *Balistes viridescens* Bloch and Schneider, 1801

Diagnosis

Nasal apertures in a depression, anterior nasal conical with an opening at the tip. Groove before eye. Scales on cheek, absent at the anterior, posteriorly 5-6 horizontal rows of small rectangular to square scales with fleshy grooves between these scale rows. Body scales have spherical protuberances. Caudal peduncle with 5-6 horizontal rows of antrose protuberance. Caudal round with lobes produced.

Bleeker (1865) published the drawings together with their names *Balistes* (*Pseudobalistes*) *flavimarginatus* as plate CCXVIII Fig.3 and *Balistes* (*Pseudobalistes*) *viridescens* plate CCXXIV Fig.3 in *Atlas ichthyologique.*

In 1866 he (Bleeker) published the description of subgenus *Pseudobalistes* and designated *Pseudobalistes viridescens* Bleeker, as the type species. The description of *Balistes viridescens* was first published by Bloch and Schneider (1801) and Bleeker's *Pseudobalistes viridescens* is co specific with this.

Fraser-Brunner (1935) erected the genus *Balistoides* with the same type species as that of *Pseudobalistes*, hence *Balistoides* Fraser-Brunner, 1935 is a junior synonym of *Pseudobalistes*, Bleeker, 1866, though none of the authors including Fraser-Brunner, 1935 mentioned it. Jordan (1917) believed that *Balistes* (*Pseudobalistes*) *flavimarginatus* Ruppell (1829) as the type species of *Pseudobalistes* apparently because this name together with its figure appeared first in *Atlas ichthyologique* of Bleeker (1865). However in about one year of publication of *Atlas ichthyologique* a revision of Family Balistidae was published by Bleeker (1866) where in he has described the genus and designated the type species. Hence the impression of Jordan (1917) that *Balistes* (*Pseudobalistes*) *flavimarginatus* is type of *Pseudobalistes* is invalid.

Thus it is concluded that the type species of *Pseudobalistes* of Bleeker (1866) is *Pseudobalistes viridescens* (Bleeker, 1866) = *Balistes viridescens* (Bloch and Schneider, 1801) and since the type of *Balistoides* of Fraser-Brunner (1935) also *Balistes viridescens* (Bloch and Schneider, 1801), it becomes the junior synonym of *Pseudobalistes.*

2.5.7. 1. *Pseudobalistes viridescens* (Bloch and Schneider, 1801)

(Figure55)

Balistes viridescens Bloch and Schneider, 1801, p. 477.
Balistes viridescens Day, 1878, p.689.
Balistoides viridescens Jones and Kumaran, 1980, p.668, fig.569.

Diagnosis

Nostrils placed in depression surrounded by spinules, anterior nostril dome shaped with a circular opening at the top. Groove before eye. Scales on cheek square at the anterior and rectangular towards the posterior, arranged in 5-6 horizontal rows with fleshy rows in between. Caudal peduncle equally long and deep, laterally elliptical, having spherical protuberances or antrose spines arranged in 4-5 rows. Ventral flap absent. Caudal fin round.

Material examined: One specimen from Kalpeni, of length of 139 mm TL, 9 specimens from Minicoy, (1 female, 5 males and 3 indeterminates) ranging from 43 to 474 mm TL, (Fig.55.D), Five specimens from Lakshadweep Islands, CMFRI-LA-F. Reg. No. 154/475, of lengths 56, 82, 107, 235, 308 mm TL.

Additional material examined: Six specimens from Tuticorin, (4 females, 2 males) of lengths 287, 370, 370, 422, 450, 527 mm TL, (Fig.55.C), three specimens from Kelakarai, (3 females) of lengths 83, 141, 326 mm TL, (Fig.55.B), one specimen from Mandapam, (female) of length of 316 mm TL, (Fig.55.A), Two specimens from Gulf of Mannar, CMFRI – F. Reg. No. 154/ 699, of lengths 105,155 mm TL.

Description

D. III, i, 21–26; P. i, 13–14; ventral spines 6–14; A. i, 22-23; C. ii, 10; Gill rakers 30-35; number of scale from origin of second dorsal to base of anal 11–15; lateral line scale 38–49; round the caudal peduncle 10–12.

As percent of head: Head height 106.25–128.87 (121.0); head width 43.75–60.81 (53.38); orbit 13.24–35.71 (20.45); interorbital 25.0–33.33 (29.59); postorbital 6.67–18.75 (12.96).

As percent of standard length: Depth 45.75–51.38 (48.90); head 35.41–43.24 (38.54); snout 26.47–29.04 (27.62); predorsal length (I) 33.43–40.54 (36.41); predorsal length (II) 61.45–70.59 (65.78); preanal length 64.68–72.37 (67.97); postdorsal length (I) 35.29–46.37 (41.79); postdorsal length (II) 5.41–8.78 (6.90); base of first dorsal 18.70–29.41 (21.81); base of second dorsal 23.53–31.84 (27.46); base of anal 21.05–28.44 (23.10); second dorsal 11.76–18.13 (15.87); anal 8.82–18.36 (16.01); pectoral 12.57–15.60 (13.84); caudal peduncle 8.11–10.53 (9.31).

Body oval, deep. Head profile, convex. Inter-orbital straight. Lips thick cylindrical, broad. Groove, longer than orbit, narrow at the anterior, broad and shallow towards posterior, with some minute sharp protuberances. First dorsal spine with small protuberances, third spine less than ¼ length of first spine. A thick "C" shaped flap covers the circular opening of anterior nostrils (Fig.56. A). The first teeth of the upper jaw conical with pointed tip diverging outside. The first teeth of the lower jaw conical with pointed tip. Other teeth are conical with a broad base (Fig.56. B).

Few scales arranged just above the base of pectoral are small, round and engraved. Gill opening oblique. The gill rakers are elongated, hyaline, pointed and laterally compressed (Fig.56. C). The second dorsal and anal fins are anteriorly elevated and posteriorly round having serrated edge. Pectoral fin round.

Square and rectangular scales on cheek have spherical protuberances arranged in 4-6 vertical rows (Fig.56.D & Fig.57.A). Body scales have vertical rows of spherical

protuberances arranged in 4-9 rows. Fresh specimens have a dark central blotch (Fig. 56.E & Fig.57.B). The ultra structure of the anterior margin of the body scale has irregular shaped projections and long ridges (Fig.57. E –G) and the posterior margin has round protuberances (Fig.57. H - J). Rectangular and rhomboid scales on abdomen have spherical protuberances arranged in oblique rows (Fig.56.F & Fig.57.C). There are two types of scales on caudal peduncle i) scales with 4-6 rows of spherical protuberances, ii) scales with a large spherical protuberance or antrose spine at the anterior middle of the scales with 3-5 vertical rows of spherical protuberance (Fig.56. G & Fig.57.D).

The ventral flap is absent. Ventral spines are transparent, elongate, thick and blunt in adults, the spines are thick, short and hyaline having pointed tips in juveniles (Fig. 56. H). Pelvic spine is movable, club shaped fully decorated with hyaline spinules, edges are stellate.

Colour

Variation in colour pattern (fresh specimens) was observed in specimens collected from south east coast (Kelakarai, Mandapam and Tuticorin) and Minicoy.

(1) **Kelakarai**

Body Olive green. **Body scales** dark green patch at the center. **Cheek** orange, with black and white band above upper lips. A dark longitudinal blotch originates at the inter-orbital to base of pectoral. **First dorsal fin** orange with few darker patches. **Second dorsal and anal fins** orange, bordered with black band. **Caudal** orange, bordered with black band. Pectoral orange (Fig. 55.B).

(2) **Mandapam**

Body Yellow. **Body scales** with a dark brown patch at the center. **Cheek** bright yellow, just above upper lip reddish brown, pink and black band. Breast pink. A dark longitudinal blotch originates at the inter-orbital to base of pectoral. **First dorsal** brown, with a pink patch at the base. **Second dorsal and anal fin** yellow,

bordered with a black band. **Caudal fin** yellow, bordered with a broad black band (Fig. 55.A).

(3) **Tuticorin**

Body bright yellow. **Body scales** brown-green colour at the center. **Cheek** orange, just at the edge of the mouth greenish yellow band, upper lip brown, lower lip pink. Just above upper lip dark brown and white band. Longitudinal blotch from inter-orbital to base of pectoral, breast pink. **First dorsal fin** brown. **Second dorsal and anal fin** brown, dark brown band at edges and base. **Caudal** yellow, with dark brown band at edges. **Pectoral fin** yellow, with orange brown edges (Fig. 55.C).

(4) **Minicoy**

Body yellow. **Body scales** brown-green at the center. **Cheek** yellow, upper lip black, lower lip pink just above upper lip a white, black and a narrow white band. Longitudinal blotch from inter-orbital to base of pectoral, breast white. **First dorsal fin** yellow. **Second dorsal and anal fin** Yellow, black band at edges and base. **Caudal** yellow, with black band at edges. **Pectoral fin** yellow, with black edges. A white-yellow blotch at caudal peduncle (Fig. 55.D).

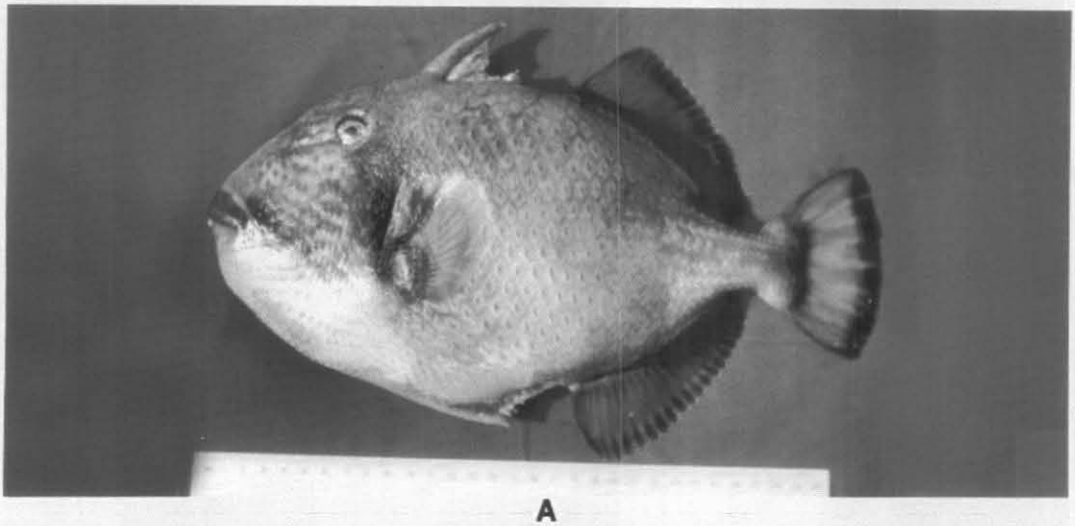
Colour of the preserved specimens: Body Brown, body scale with a black blotch at the enter. Longitudinal blotch from inter-orbital to base of pectoral.

Distribution

Mauritius (Bloch and Schneider, 1801); Red sea, New Guinea (Hollard, 1854); Red sea, Zanzibar, Mauritius (Gunther, 1870); Maldives, (Jones *et al.*, 1981); Sanguisiapo (Sulu Archipelago), Waruh-Bucht (Ceram), Haingsis Island (Samau) (Weber, 1913); Badjoa, Tanawanka (Celebes), Ambonia (Bleeker, 1849,1857); Hood Bay (New guinea) (Macleay, 1883); New Georgia Island, Solomon Islands, Suva Harbour, Viti Levu Island (Fiji) (Herre, 1936); Eniwetok Island, Bikini Island (Schultz, 1966), Ishigaki Island, Ryukyu Islands (Japan) (Matsuura, 1980); Eniwetok (Marshall Islands),

Society Islands and Red sea (Randall, 1980); Sesoko Island (Japan); (Kuwamura, 1991); Chinsan (Taiwan) (Shao *et al.*, 1994) (Fig. 58.A & B).

Remarks: The fishes collected from Kelakarai, Mandapam, Tuticorin and Minicoy Islands, showed some variations in the colour pattern. These fishes were very rare in the catches and only 27 specimens could be collected during the study period.



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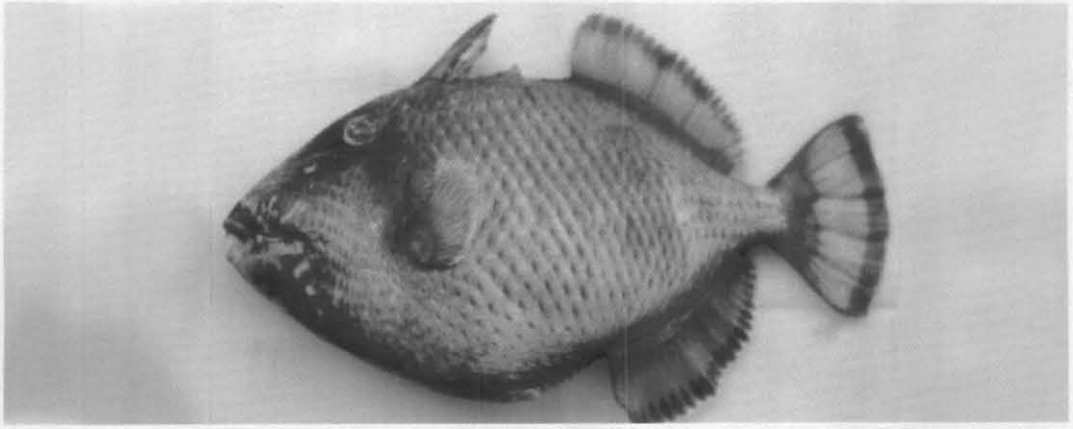

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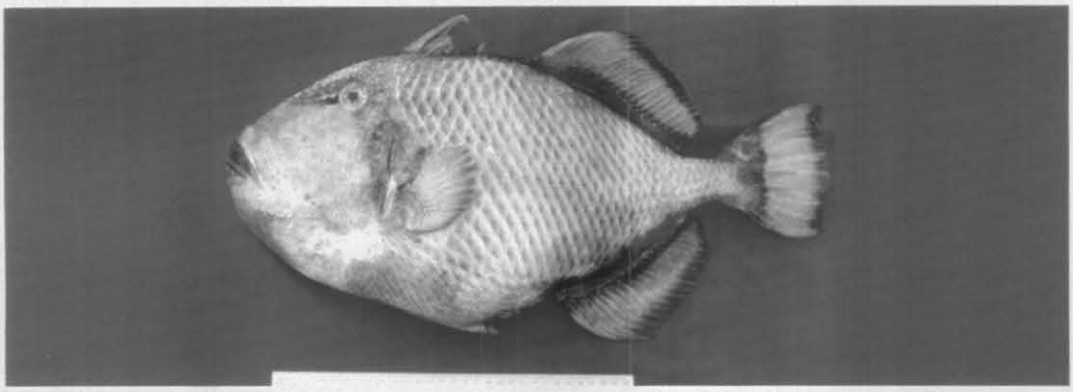

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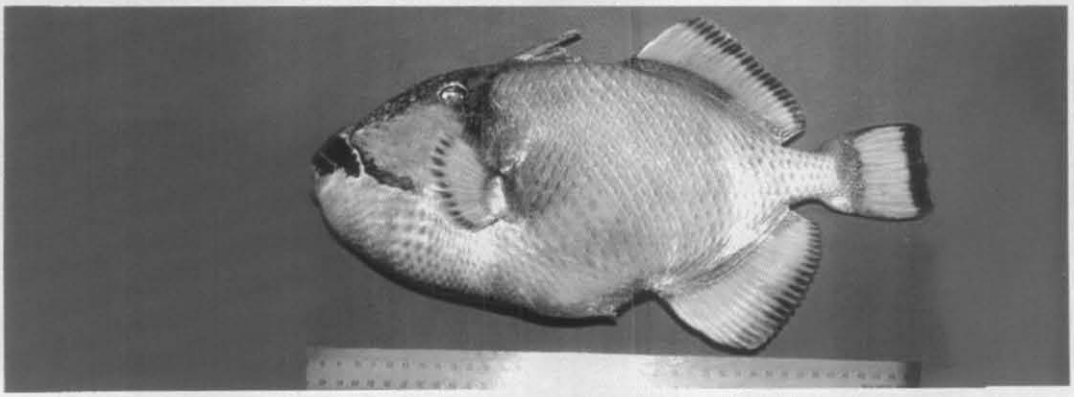


D

Figure 55. *Pseudobalistes viridescens* (Bloch and Schneider, 1801) : A. From Mandapam 316 mm TL, B. From Kelakarai 326 mm TL, C. From Tuticorin 527 mm TL, D. From Minicoy 455 mm TL.

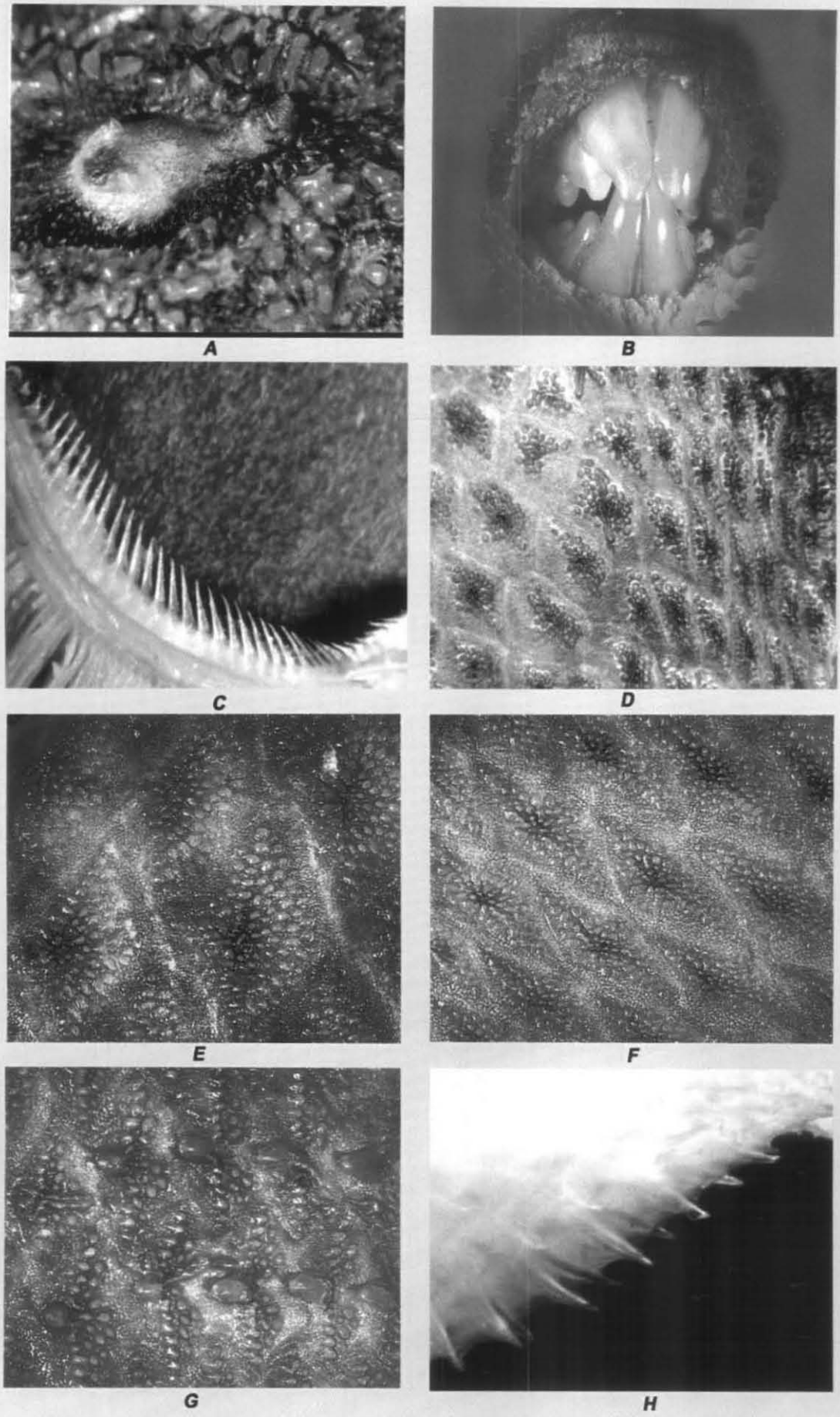


Figure 56. *Pseudobalistes viridescens* (Bloch and Schneider,1801): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

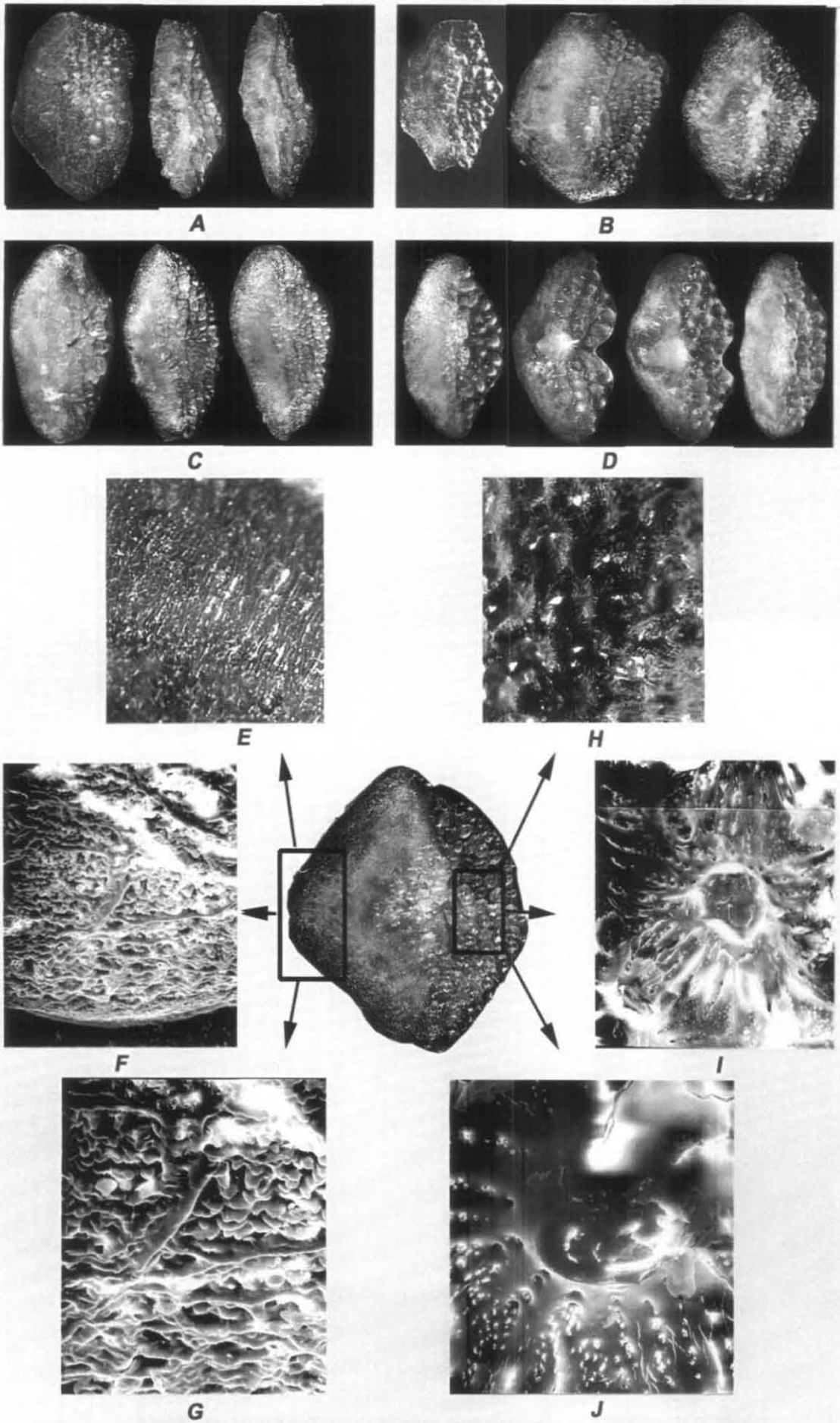
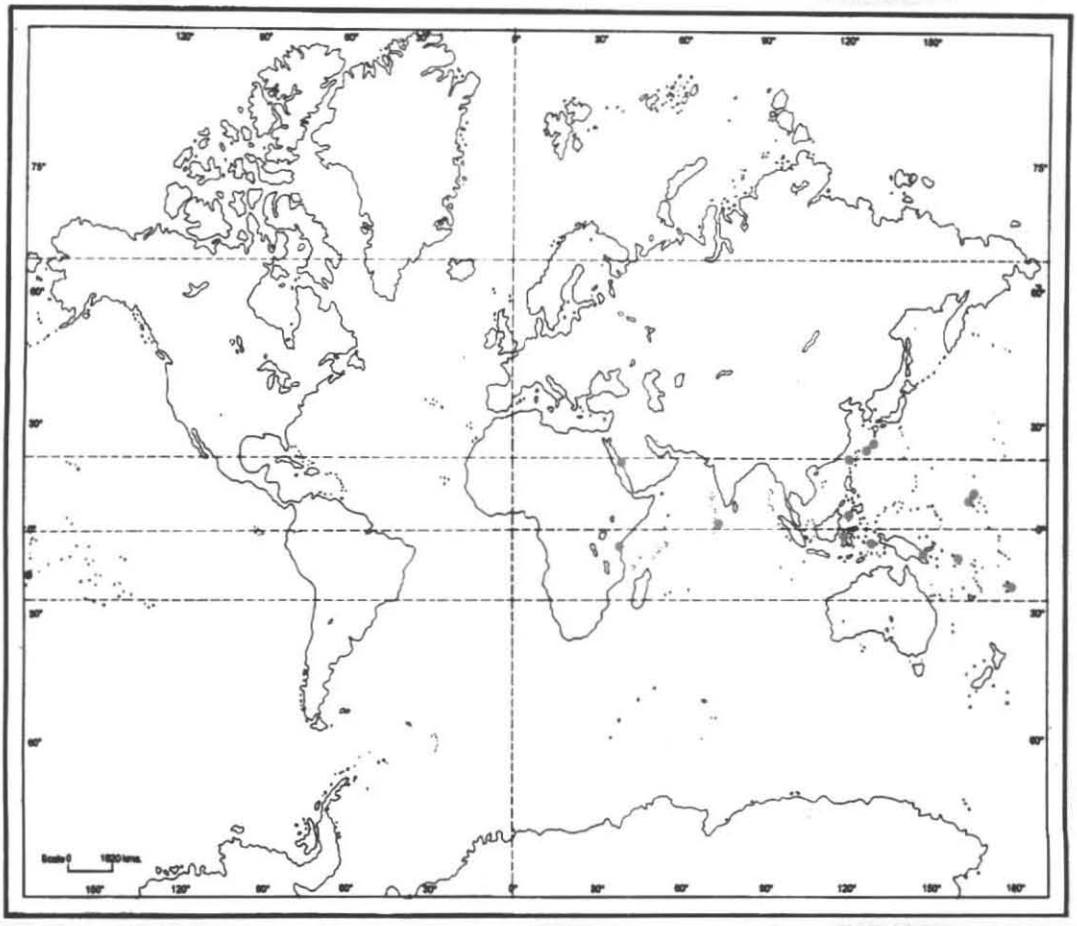
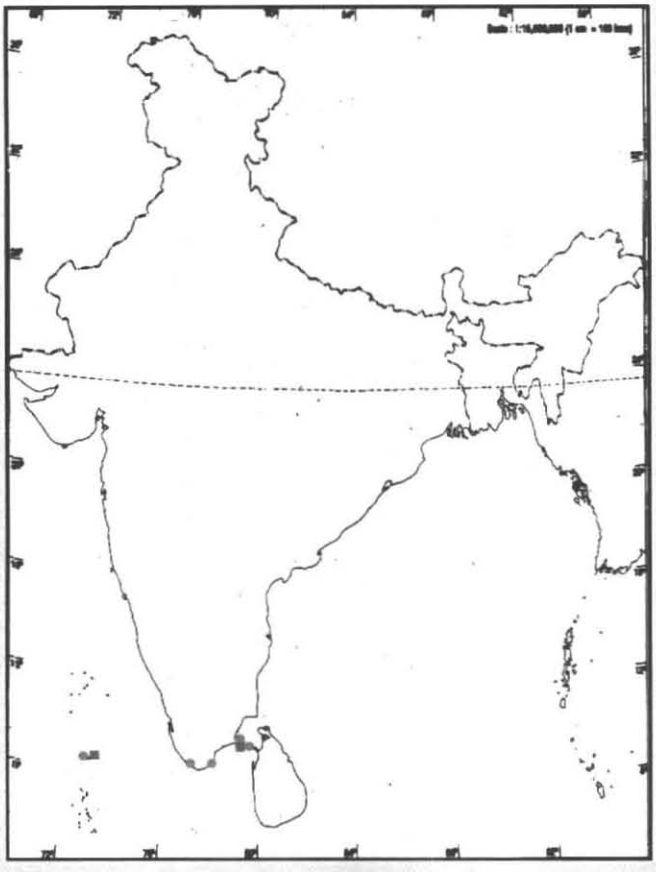


Figure 57. *Pseudobalistes viridescens* (Bloch and Schneider, 1801) : A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.



A



B

Figure 58. *Pseudobalistes viridescens* (Bloch and Schneider,1801) : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.7. 2. *Pseudobalistes flavimarginatus* (Ruppell, 1828)

(Figure 59)

Balistes flavimarginatus Ruppell, 1828, p. 33.
Balistes flavimarginatus Day, 1878, p.690.
Pseudobalistes flavimarginatus Jones and Kumaran, 1980, p. 671, fig.571.

Diagnosis

Anterior nostril, in a depression, dome shaped with a circular opening at the top, Groove before eye. Scales on cheek absent anteriorly, posteriorly square arranged horizontally in 5-6 narrows rows with fleshy rows in between. Body scales with spherical protuberances. Caudal peduncle longer than deep with 4-5 rows of sharp ridge or blunt spherical protuberances. Caudal truncate with lobes produced.

Material examined: One specimen from Minicoy, (female) of length of 233 mm TL, two specimens from Minicoy, of lengths 273, 233 mm TL, four specimens from Minicoy, (3 females, 1 male) of lengths 271, 324, 429, 435 mm TL, (Fig. 2.5.7.5.A), four specimens from Minicoy, CMFRI-F. Reg. No. 154/447, of lengths 123, 160, 160, 287 mm TL, one specimen from Agatti, CMFRI-LA-F. Reg. No. 154/443, of length of 317 mm TL, (Fig.59.D), one specimen from Minicoy, CMFRI Reg. No. 2251, of length of 183 mm TL,

Additional material examined: Two specimens from Tuticorin, of lengths 484, 490mm, TL, (Fig.59.B), one specimen from Mandapam, (female) of length of 345 mm TL, (Fig. 59.C) one specimen from Andaman, ZSI Reg. No. 2251, of length of 183 mm, TL, collected by Dr. F. Day (Fig.59.E).

Description

D. III, i, 24-25; P. i, 13-14; ventral spines 8-13; A. i, 23-24; C. ii, 10; Gill rakers 29-31; number of scales from origin of second dorsal to base of anal 12-14; lateral line scales 44-51; round the caudal peduncle 10-11.

As percent of head: Head height 129.49–141.28 (134.27); head width 52.63–55.38 (54.11); orbit 16.10–23.08 (18.55); interorbital 33.33–35.78 (34.21); postorbital 11.11–14.41 (12.88).

As percent of standard length: Depth 50.92-53.33 (52.43); head 35.39–37.14 (36.30); snout 27.61–29.39 (28.42); predorsal length (I) 31.49–36.67 (34.19); predorsal length (II) 60.06–65.24 (63.03); preanal length 64.29–66.29 (65.32); postdorsal length (I) 42.70–47.08 (44.51); postdorsal length (II) 3.77–7.47 (6.08); base of first dorsal 18.57–23.60 (21.30); base of second dorsal 29.05–32.47 (30.89); base of anal 28.25–30.19 (29.02); second dorsal 15.73–19.05 (17.91); anal 16.85–19.94 (18.44); pectoral 13.06–14.61 (14.13); caudal peduncle 9.20–10.11 (9.72);

Body oval. Head profile convex. Lips broad, thin and narrow at the center. Interorbital convex. Groove, straight, equal to orbit, narrow and shallow towards anterior, deep and broad posteriorly. First dorsal spines strong, stout, laterally compressed, broad. Numerous spinules, at the anterior portion with larger spinules at tip. Anterior nostril covered by a "C" shaped flap. Posterior nostril circular and placed slightly elevated from the anterior nostril, (Fig. 60.A). The first teeth of the upper and lower jaw conical with pointed tip, tips diverge in case of upper jaw. The other teeth are rectangular elongated with the upper end conical towards one side (Fig.60.B).

Scales above the pectoral base is arranged in an irregular fashion having round, rectangular and hexagonal shapes. Gill opening vertical. The gill rakers are elongated, blunt tipped, laterally flat, with rough inner edge (Fig.60.C). The second dorsal and anal is elevated anteriorly and short and rounded posteriorly with a wavy edge. Pectoral fin rounded.

Scales on the cheek are of two types i) scales on cheek with 1- 4 vertical rows of spherical protuberances with few ridges. ii) scales covered by skin with smooth surface and shallow depressions and ridges (Fig.60.D & Fig.61.A). Body scales, with a dark

blotch at the center and have 5 – 6 vertical columns of spherical blunt protuberances (Fig. 60.E & Fig.61.B). The ultra structure of the anterior margin of the body scale has network of fibers (Fig.61. E –G) and the posterior margin has round protuberances (Fig. 61. H - J). Scales on abdomen have ridges on the first row followed by 3-5 oblique rows of round protuberances (Fig.60.F & Fig.61.C). There are two types of scales on caudal peduncle i) scales with spherical or sharp ridges at the anterior middle of the scale. ii) Scale with spherical protuberance arranged in 3-4 vertical rows (Fig.60.G & Fig. 61.D).

The anterior ventral spines are transparent, elongated; posterior spines are broad and pointed (Fig.60.H). The ventral pelvic spine is rectangular and laterally elliptical with large number of blunt protuberances.

Colour

Variation in colour pattern (fresh specimens) was observed in specimens collected from south east coast (Mandapam and Tuticorin) and Minicoy.

(1) **Minicoy**

Body grey, upper and lower lips orange. **Cheek**, orange, with dorsally lighter and ventrally darker. **First dorsal** brown. **Second dorsal, Anal and caudal fins** have red, grey and a narrow orange band at the edge. **Pectoral** yellow bordered with orange (Fig. 59.A).

(2) **Tuticorin**

Body dark brown. Upper and lower lips pink. **Cheek** dorsally dark brown ventrally orange. **First dorsal** black. **Second dorsal, anal and caudal fins** have orange and grey band at the edge. First and last ray of second dorsal, anal and caudal fin bright red (Fig. 59.B).

(3) **Mandapam**

Body yellow. Upper and lower lips are orange. **Cheek** is orange, dorsally lighter and ventrally darker. **First dorsal** brown. **Second dorsal, anal and caudal fins** have red, grey and narrow orange band at the edge. **Pectoral** yellow bordered with orange (Fig. 59.C).

Colour of the preserved specimens: The whole fish is brown (Fig.59.D).

Distribution

Jeddah, Red sea (Ruppell, 1835); New Guinea (Bleeker,); Ambonia, Ceram, Banda (Sumatra), Makassar, Badjoa, Manado (Celebes) Bawean, Batjan, (Bleeker, 1859, 1860, 1865); Red sea, Ambonia (Gunther, 1870); Andaman (Day, 1878); Short Island, (Solomons Islands) (Seale, 1906); Bacon (Philippines) (Everman and Seale, 1907); Cuyo (Philippines) (Jordan and Richardson, 1908); Island Kapul (Sulu Archipelago), Island Siau, Buton-Strasse (Max Weber, 1913); Wakanoura, Misaki, Sagami (Japan) (Jordan *et al.*, 1913); Ishigaki Island, Ryukyu Islands (Japan) (Matsuura,1980); Maldives (Jones *et al.*, 1981); Yehliu (Taiwan) (Shao *et al.*, 1994); Bikini Island (North Western Australia) (Allen and Smith, 1996) (Fig. 62.A & B).

Remarks: The fishes collected from Mandapam, Tuticorin and Minicoy Islands, showed some variations in the colour pattern. These fishes were very rare in the catches and only 14 specimens could be collected during the study period.

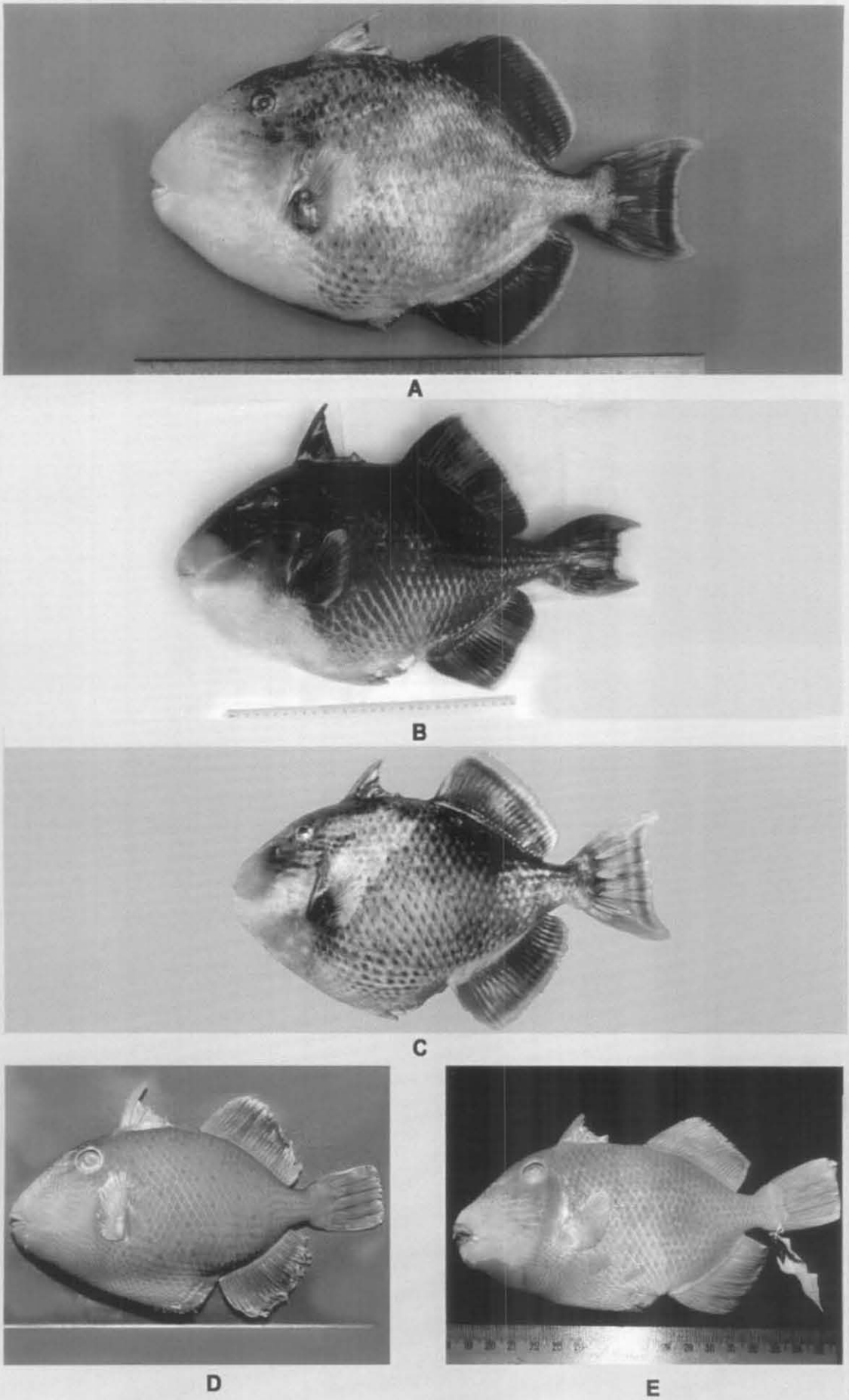


Figure 59. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. From Minicoy 435 mm TL, B. From Tuticorin 490 mm TL, C. From Mandapam 345 mm TL, D. From Agatti CMFRI-F.154/443, 317 mm TL, E. From Andaman ZSI Reg. No. 2251, 183 mm TL, collected by Dr. F. Day.

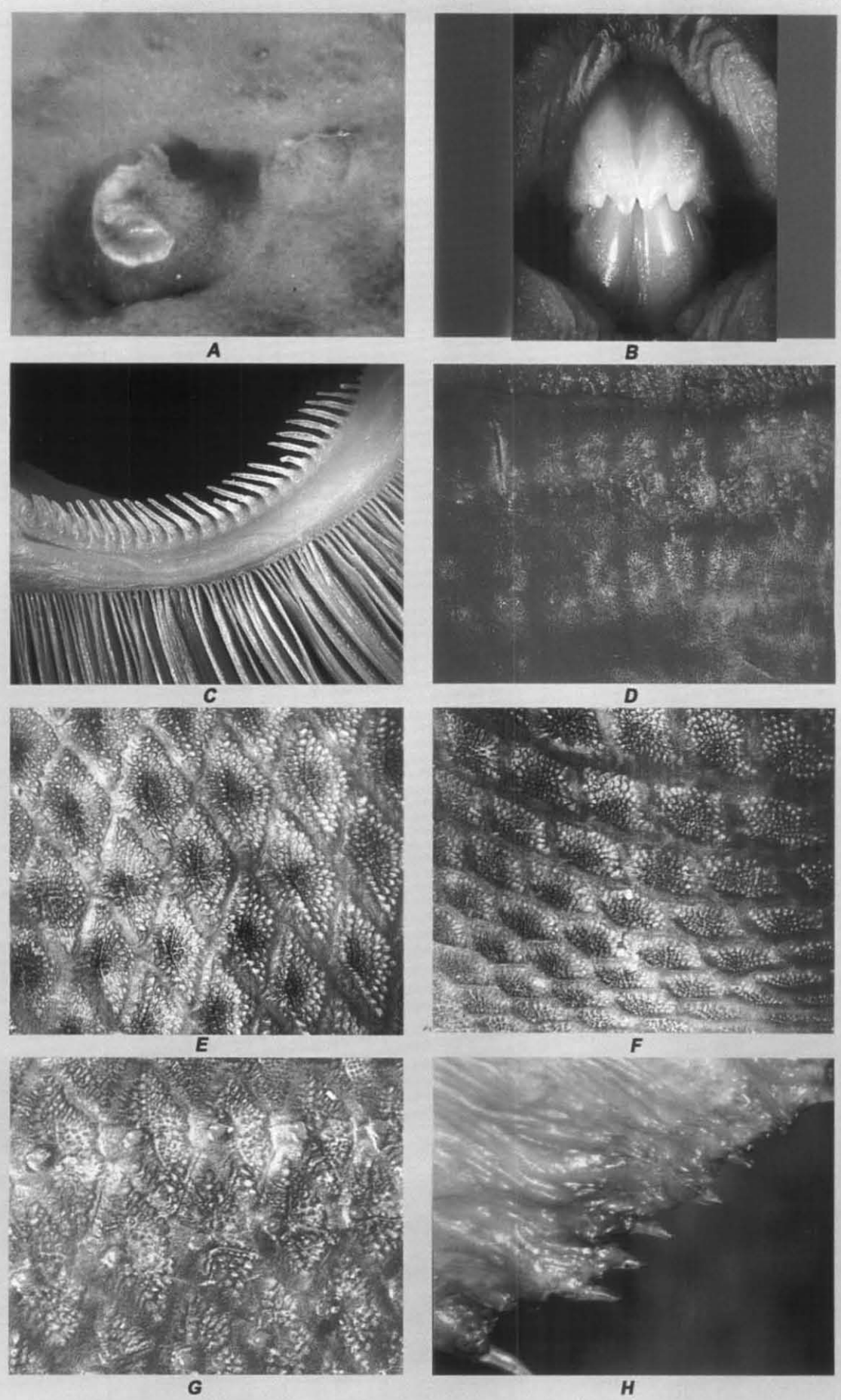


Figure 60. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

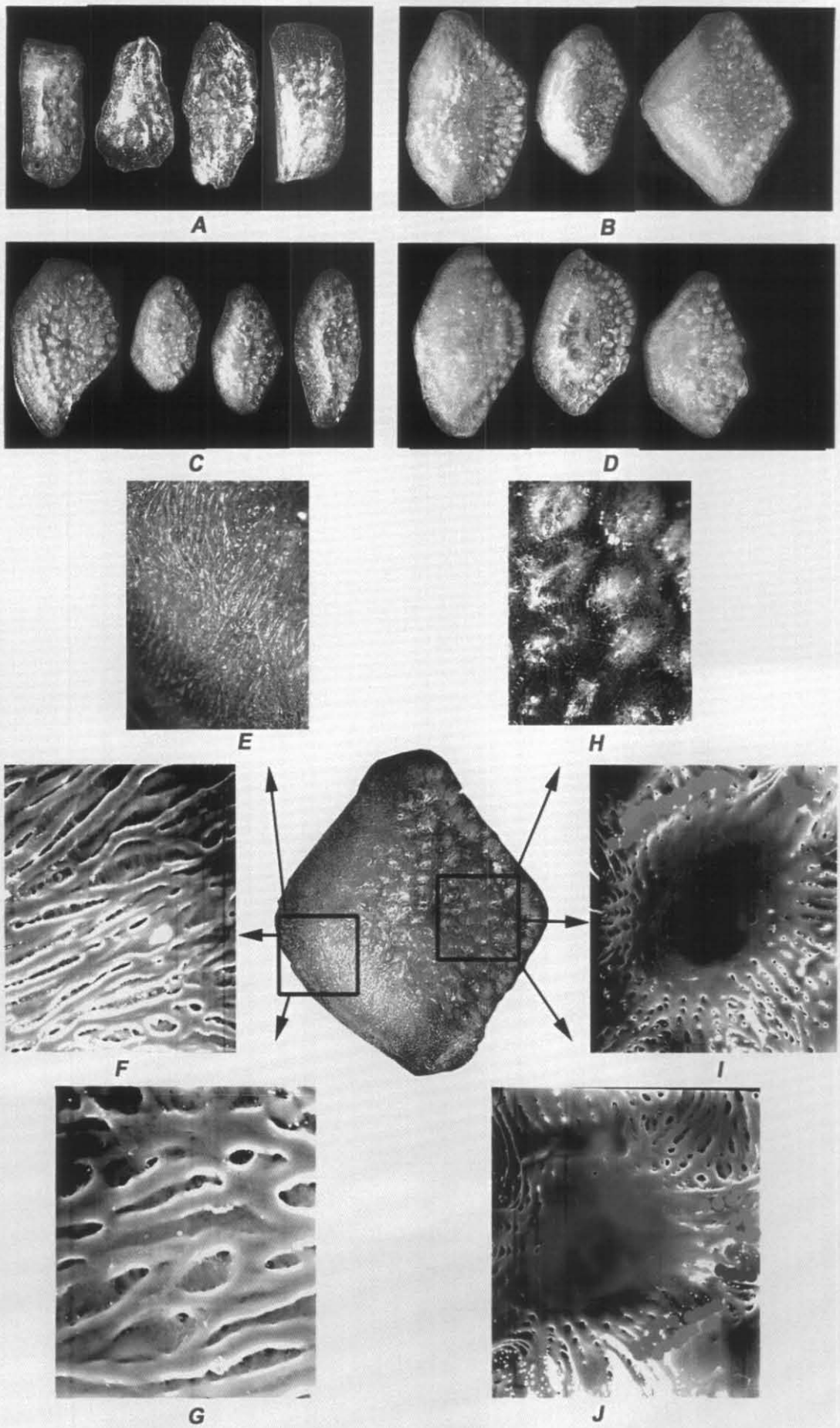
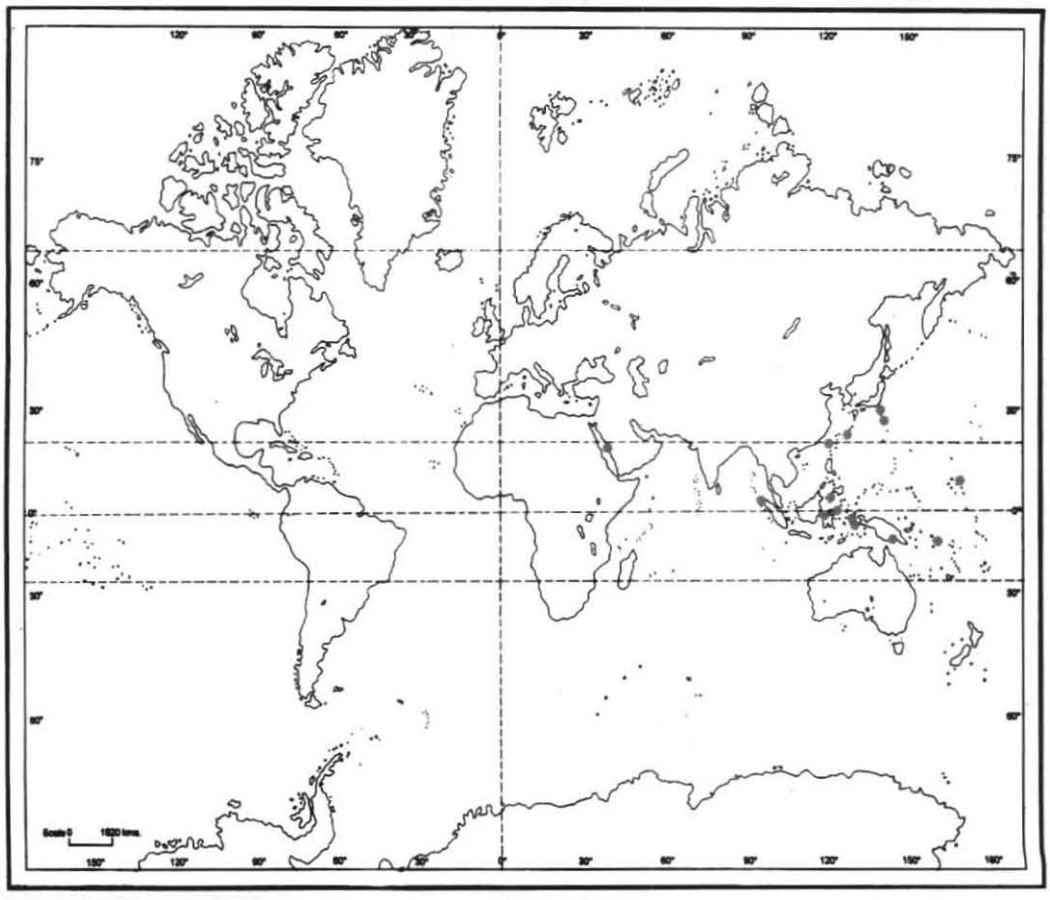


Figure 61. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.



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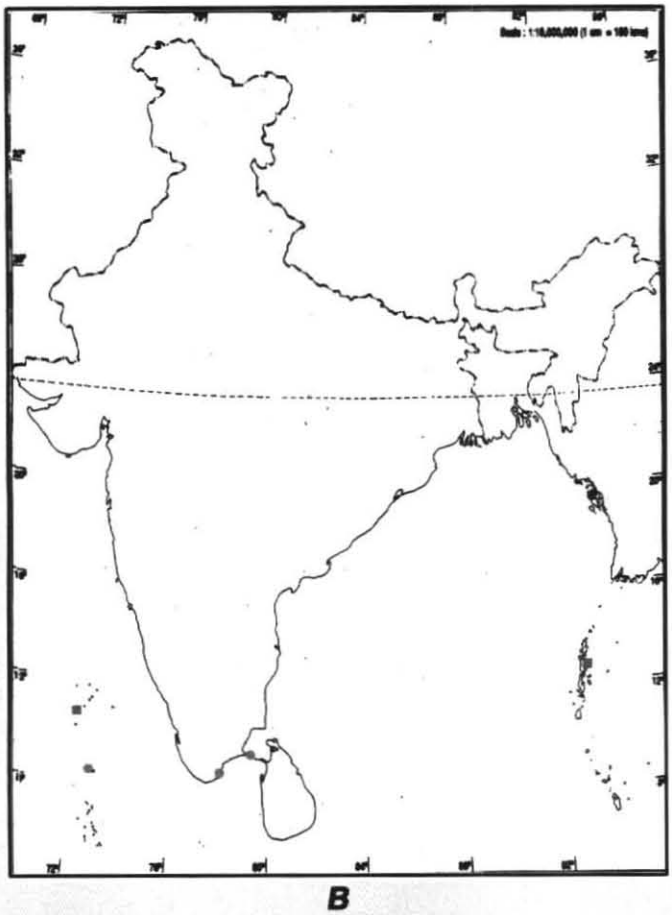


B

Figure 62. *Pseudobalistes flavimarginatus* (Ruppell, 1828): A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.7. 3. *Pseudobalistes conspicillum* (Bloch and Schneider, 1801)

(Figure 63)

Balistes conspicillum Bloch and Schneider, 1801, p.474.
Balistes conspicillum Day, 1878, p.689.
Balistoides conspicillum Jones and Kumaran, 1980, p.670, fig.570.

Diagnosis

Nostrils in a shallow depression, anterior nostril conical with a circular opening at the top. Groove before eye. Scales on cheek diamond shaped, obliquely arranged at the anterior and vertical posteriorly. Body scales with spherical protuberances. Caudal peduncle equally deep and long cylindrical, having two rows of spherical protuberances. Ventral flap absent. Caudal round.

Material examined: One specimen from Lakshadweep, CMFRI. Reg. No. CMFRI-LA-F-154/476, of length of 282 mm TL (Fig. 63).

Description

D. III, i, 25; P. i, 13; ventral spines 20; A. i, 21; C. ii, 10; number of scales from origin of second dorsal to base of anal 21; lateral line scales 57; round the caudal peduncle 11.

As percent of head: Head height 135.90; head width 58.97; orbit 17.95; Interorbital 32.05; postorbital 6.41; length of first spine 64.10.

As percent of standard length: Depth 40.52; head 33.62; snout 25.43; predorsal length (I) 33.19; predorsal length (II) 66.81; preanal length 76.29; postdorsal length (I) 44.83; postdorsal length (II) 4.31; base of first dorsal 21.98; base of second dorsal 28.88; base of anal 19.40; second dorsal 9.91; anal 9.48; pectoral 9.48; caudal peduncle 7.33;

Body oval. Head profile, dorsally concave, ventrally convex. Lips, thick, cylindrical. Eye placed high. Inter-orbital straight. Groove equal to orbit, narrow towards the anterior, broader and deep towards the posterior, parallel to head profile. First dorsal

spine broad, blunt, with small protuberances at the anterior portion. Third spine, less than ¼ the length of first spine. Opening of the anterior nostril covered by a "C" shaped thick flap.

Rectangular scales placed in a rectangular area just above pectoral base. Gill opening vertical. Second dorsal and anal fins, have a convex profile. The length of anal fin base is half to that of second dorsal fin base; both the fins are translucent Pectoral fin round.

Scales on cheek have 3–4 vertical rows of round protuberances (Fig.64.A). Body scales with a spherical pointed protuberance at the anterior middle and 4-6 vertical rows of round protuberances (Fig.64.B). Scales on abdomen rectangular or rhomboid arranged in oblique rows with round protuberances also arranged in oblique rows (Fig.64.C). Scales on caudal peduncle are of two types i) scales with a large spherical protuberance at the anterior middle of the scale and round protuberances, ii) scales with round protuberances arranged in vertical rows (Fig.64.D).

Ventral spines 20 in number arranged in a single row with the spines from either side alternating. Each spine is a triangular projection arising from the lateral side of an elongated rectangular scale (Fig. 2.5.7.10.E). Rudimentary pelvic spine short stout has minute spinules.

Colour

Formalin preserved fish, dark brown. Lips pink, behind lips pink followed by a circular whitish-brown ring. Whitish-brown band below eye. First dorsal fin black. Second dorsal and anal fin pink and translucent. Caudal brown edge blackish - brown. Ventrally 6–7 circular to hexagonal whitish-brown patches arranged in three rows. Caudal peduncle has broad whitish-brown streak (Fig.63).

Distribution

Sumatra (Park, 1797); Indian Seas (Schneider, 1801); Makassar [Celebes], Solor, Ambonia, New guinea, Komoniwo [Japan], Singapore (Bleeker, 1849, 1853, 1857, 1859, 1860, 1865); Natunas, Singapore, Pinang (Cantor, 1850); Nikobaren (Kner, 1865);

Japan, Formosa, Pinang, Singapore (Gunther, 1870); Bacon [Philippines] (Everman and Seale, 1907); Yaeyama, Miyako Island [Japan] (Schmidt, 1930); Rennell [Solomon Island], Aneiteum [New Hebrides] (Whitely, 1937); Jaluit Atoll [Marshall Island] (Weber and Beaufort, 1962); Okinawa Island, Ryukyu Island, Ishigaki Island [Japan] (Matsuura, 1980); Maldives (Jones *et al.*, 1981); Andaman (Manickasundaram and Ramaiyan, 1990); Wanlitung [Taiwan] (Shao *et al.*, 1994); (Fig.65.A & B).

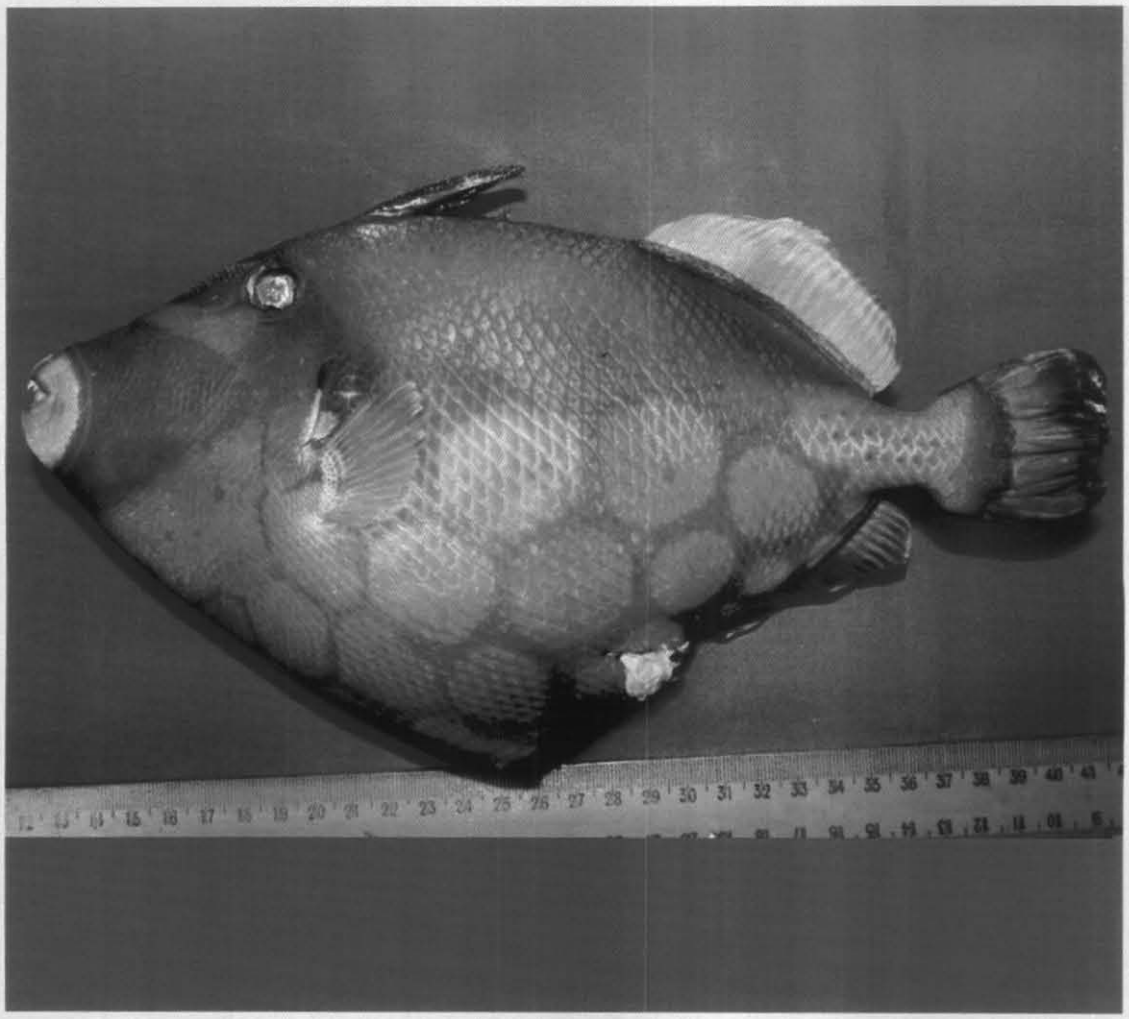
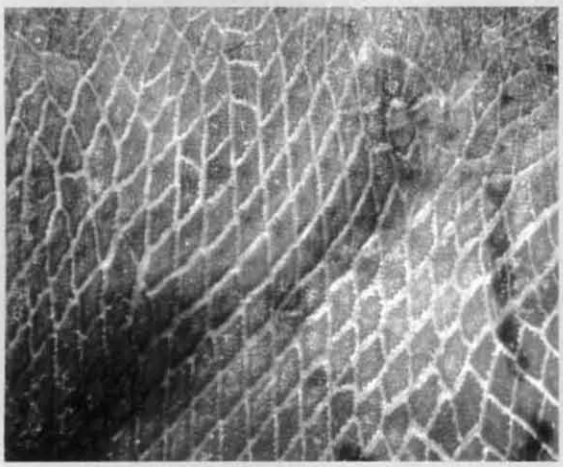


Figure 63. *Pseudobalistes conspicillum* (Bloch and Schneider, 1801) : From Lakshadweep 282 mm TL.



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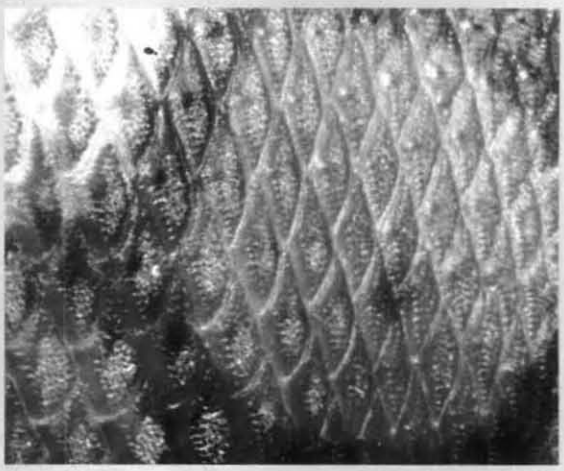

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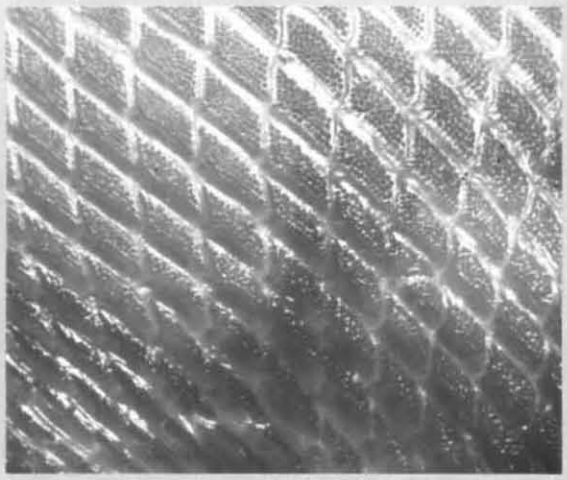

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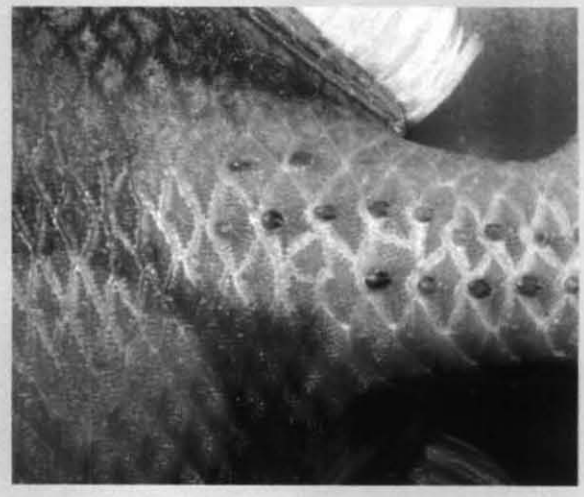

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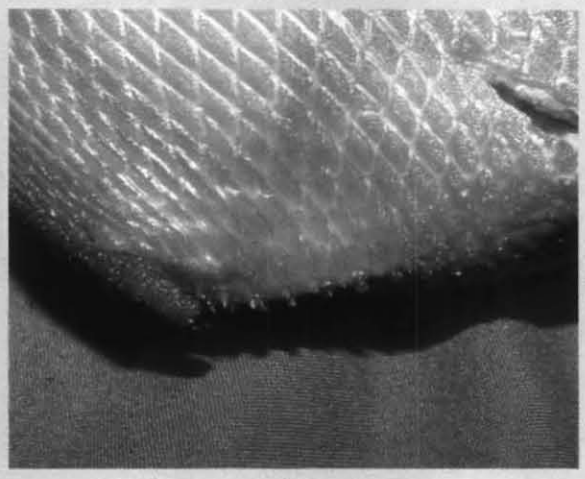
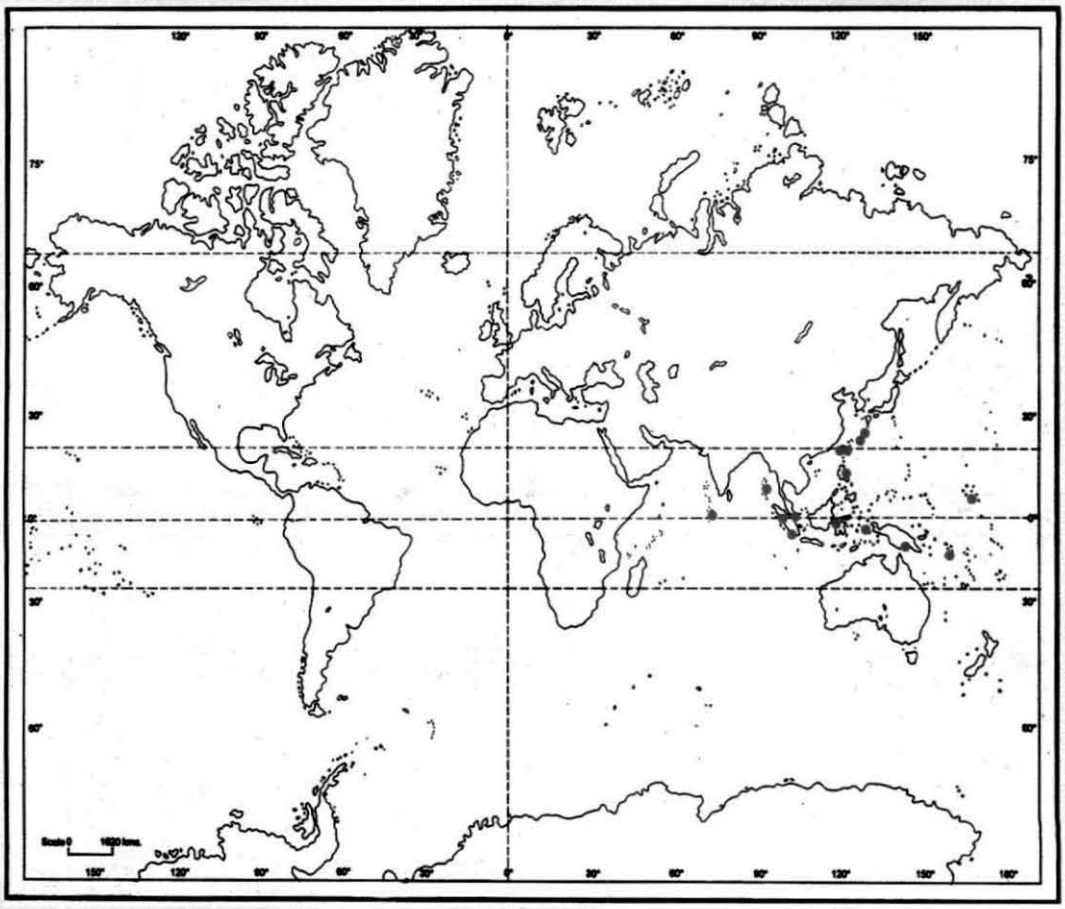
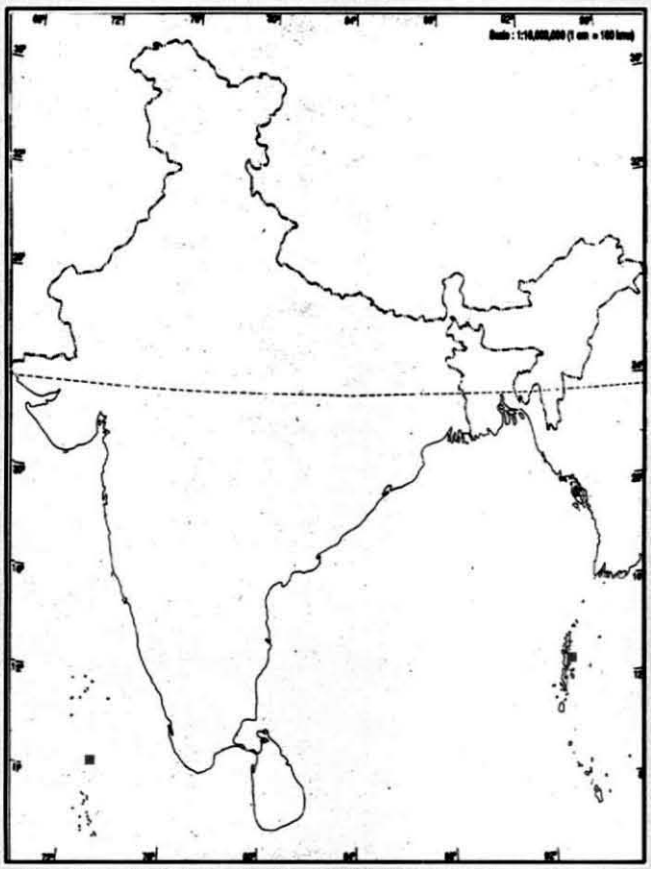


E

Figure 64. *Pseudobalistes conspicillum* (Bloch and Schneider,1801): A. Scales on cheek, B. Body scales, C. Scales on Abdomen, D. Scales on caudal peduncle, E. Ventral spines.



A



B

Figure 65. *Pseudobalistes conspicillum* (Bloch and Schneider,1801) : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections.

2.5.8. *Sufflamen* Jordan, 1916

(Type species *Balistes capistratus* Shaw, 1804 = *Balistes fraenatus* Latreille,1804)

Diagnosis

Anterior nasal aperture dome shaped with a circular opening or tube directed forward. Scales on cheek rectangular or square or rhomboid with round protuberances. Groove before eye. Body scale with blunt retrose spine. Caudal peduncle equally long and deep. Caudal peduncle with five to eight rows spherical protuberances or antrose spines. Caudal emarginate or lunate.

2.5.8. 1. *Sufflamen fraenatus* (Latreille, 1804)

(Figure 69)

Balistes fraenatus Latreille, 1804, p.74.
Balistes mitis Day, 1878, p.689.
Balistes verres Gilbert and Stark, 1904, p.153, fig. 49.

Diagnosis

The nostrils placed in a circular depression, anterior nostril dome shaped with an opening at the tip. Scales on cheek rectangular arranged in horizontal rows with round protuberances. Groove before eye. Body scales have round protuberances. Caudal peduncle equally deep and long, have 5-10 rows of spherical protuberance. Caudal lunate with lobes produced.

Material examined: 30 specimens from Colachel, (17 females, 13 males) ranging from 156 to 291 mm TL, 30 specimens from Vizhinjam, (18 females, 12 males) ranging from 184 to 334 mm TL (Fig. 69.A), 29 specimens from Vizhinjam, (indeterminate) ranging from 85 to 118 mm TL, two specimens from Vizhinjam, CMFRI Reg. No. 154/441 and 442, (male and indeterminate) of lengths 120,166 mm TL (Fig. 69. D).

Additional material examined: Eight specimens from Tuticorin, (3 females, 5 males) ranging from 203 to 292 mm TL, three specimens from Chennai, (indeterminate) of lengths 94, 96, 102 mm TL, one specimen from Akyab bazaar, ZSI Reg. No. 10622, 182 mm TL (Fig.69.C) one specimen from Travancore, coast ZSI Reg. No. F 4160/1, 205 mm TL.

Description

D. III, i, 28–32; P. i, 13–15; ventral spines 9–21; A. i, 25-29; C. ii, 10; gill rakers 25-30: number of shield from origin of second dorsal to base of anal 21–28; lateral line shields 41-50 + 22–27; round the caudal peduncle 13–17.

As percent of head: Head height 106.45–140.0 (120.91); head width 36.67–63.89 (50.26); orbit 14.58–25.93 (21.67); interorbital 21.43–31.25 (26.30); postorbital 3.13–20.83 (8.70). The regressions of different head dimensions on head are given in figure 66.

As percent of standard length: Depth 36.59–52.16 (44.99); head 32.95–41.06 (35.87); snout 23.86–33.11 (26.88); predorsal length (I) 32.0–38.96 (35.34); predorsal length (II) 60.10–75.50 (64.45); preanal length 61.45–68.29 (65.26); postdorsal length (I) 35.26–49.73 (43.73); postdorsal length (II) 3.76–18.38 (5.74); base of first dorsal 14.71–27.06 (20.84); base of second dorsal 23.17–34.94 (30.25); base of anal 24.39–33.92 (28.49); second dorsal 10.0–19.59 (14.50); anal 9.09–16.03 (12.91); pectoral 9.59–13.41 (11.50); caudal peduncle 6.85–10.53 (8.39). The regressions of different body dimensions on standard length are given in figure 67 & 68.

Body rhomboid. Head profile straight with a prominent chin. Eye placed high. Inter orbital convex. Groove longer than orbit, deep, narrow at anterior, broader at posterior. First spine stout laterally compressed smooth, anteriorly flat with minute spinules, which are broad and blunt towards tip. Anterior nostril has a fleshy cone like projection from the inside at the opening (Fig.70.A). The first teeth of the upper and lower jaw conical with pointed tip, other teeth rectangular with upper side uneven (Fig. 70.B).

Enlarged scales arranged on a loose membrane above the base of pectoral. Gill opening oblique. Gill rakers narrow, elongated, with pointed and fragile tip (Fig.70.C). The second dorsal and anal is anteriorly elevated and posteriorly rounded. Fins are thick at base thin at tips. Pectoral round.

Scales on cheek have round protuberances arranged in 6-9 vertical rows (Fig.70. D & Fig.71.A). The body scales have ridges on the first row and 3-6 vertical rows of blunt retrose spines (Fig.70. E & Fig.71.B). The ultra structure of the anterior margin of the body scale has irregular shaped projections (Fig.71. E–G) and the posterior margin has first row of ridges and retrose spines (Fig.71. H-J). The scales on Abdomen are rectangular with the first row of ridges and 3-6 oblique rows of round protuberances (Fig. 70.F & Fig.71.C). Scales on caudal peduncle have a spherical protuberance at the anterior middle of the scale and 4-6 rows of ridges and blunt retrose spines (Fig.70. G & Fig. 71.D).

Ventral flap present with hyaline pointed spines (Fig.70.H). Pelvic spine movable.

Colour

Body brown, abdomen yellow. Iris golden when fresh. Lips pink to red in colour. Yellow or grey band above upper lip, white band below the lower lip together form a complete circle around mouth. In some specimens a lateral pink or red or white band originates at the edge of the mouth up to base of pectoral across the cheek. The first dorsal black. Second dorsal and anal are black at the base and yellowish or transparent at outer margin. Pectoral yellow. Caudal dark brown to black (Fig.69.A).

Colour of the preserved specimens: Body brown. White band below lower lip. Another white band across cheek originating from edge of mouth up to base of pectoral, in case of male (Fig.69.C & D).

Distribution

Coromandelia (India), Sumatra, Celebes, Ambonia, Padang (Sumatra) Makassar (Celebes) (Bleeker, 1852, 1859,1860); Zanzibar, Port Natal, Mauritius, China, observatory Island, Gonzalez Island. (Gunther, 1870); Honolulu, Nukuhiva, Marquesas Islands (Jenkins, 1904); Hilo (Hawaiian Island) (Jordan and Everman, 1905); Hawaii, Nukuhiva, East Indies, Ryukyu Island; Wakanoura (Jordan *et al.*, 1913); Jamillo,

Batangas, Zamboanga (Philippines) (Herre, 1924): Lodestone Reef, Towns villa, Queens land (Whitely, 1937); Tai-Ohae Bay, Comptroller Bay (Nukuhiva), Vaico bay, (Ua Pau Island), Roa-Reposa bay (Fatu Hiva) (Fowler, 1938); Venados and Creston Islands at Mazatlan and from Lapaz and Chatham Island (Jordan and Everman, 1963); Marianas Island, Rota Islands (Schutlz, 1966); Vizhinjam (India) (George and Nazir, 1976); Wan-li-tung (Taiwan) (Chang *et al.*, 1978); Ishigaki Island, Ryukyu Island, Okinawa Island (Japan) (Matsuura, 1980); Sesoko Island (Japan) (Kuwamura, 1991); Thailand (Nateewathana, 1993); Nanfangao (Taiwan) (Shoa *et al.*, 1994); Cocos Island (North Western Australia) (Allen and Smith, 1996) (Fig. 72.A & B).

Remarks: A yellow band above upper lips, in case of male and grey in case of female. A horse bridle like band around mouth and cheek, which extends till base of pectoral, which is present in male. It is white in immature males but pink to red in mature male.

Taxonomic Note

Gilbert and Stark (1904) described *Balistes verres* and observed

> " We describe as new the species that has commonly been referred to as *B. capistratus* on the Pacific coast of Central America. *B. capistratus* was probably based on east Indian material but we have had for comparison specimens from the Hawaii Islands only. From this *B. verres* differs in having smaller scales and a greater number of dorsal and anal rays. Specimens from Panama and Mazatlan have the scales 58 - 65; the dorsal has 30-32 rays and anal 28 or 29. Five specimens of *B. capistratus* from Hawaii have 50 or 51 oblique series of scales (counted from the upper end of gill opening); the dorsal has 29 or 30 rays; the anal has 25-27 rays. Caudal fins of the Hawaiian specimen are truncate, with outer rays not produced. The caudal is noticeably lunate in the Panama and Mazatlan specimens."

According to Berry and Baldwin (1966)

> " *Sufflamen verres* is closely related to *S. fraenatus* (Latreille) [= *S. capistratus* (Shaw) = *S. mitis* (Bennett)] which ranges from Hawaii westward to South Africa. The two species are very closely similar in Morphology and in adult pigmentation. Specimens of *S.*

fraenatus from the central Pacific have lower number of soft rays (about D. 28-30, A. 24-26) than *S. verres*; but a specimen of *S. fraenatus* (ANSP 101164) from South Africa, at western extreme of the range, has D. 31 and A. 27, very similar to *S. verres*".

The meristic characters of *Sufflamen fraenatus* of west coast of India and *Sufflamen verres* Pacific coast of Central America are given in the following table.

The meristic characters of *Sufflamen fraenatus* and *Sufflamen verres*	*Sufflamen fraenatus* n.90 (south west coast of India)	*Sufflamen verres* n 60 (Pacific coast of central America) Berry and Baldwin (1966)	*Sufflamen verres* n 6 (Pacific cost of central America) Gilbert and Stark (1904)
Dorsal	III, 30-33	III. 30-33	III. 30-32
Anal	27- 30	27-30	28-29
Pectoral	14-15	14-15	
Caudal	12	12	

The species cannot be distinguished with the help of meristic characters.

The caudal fin shape cannot be considered as marked variation as believed by Gilbert and Stark (1904), because the specimens in different length groups show different caudal fin shapes. The smaller (80-200 mm) length groups have truncate caudal fin and the larger length groups (250-300 mm) have lunate caudal fin, specimens above 300 mm have double lunate caudal fin.

The sexual dimorphism in *Sufflamen verres* was observed by Berry and Baldwin (1966) from the eastern Pacific. A similar observation was made from east coast of India. A detailed study on the sexual dimorphism revealed that the immature males have white bridle like band and maturing and mature males have pink and bright red band.

Thus it is clear that both the species *S. fraenatus* and *S. verres* are similar and *S. verres* should be considered as a junior synonym of *S. fraenatus*.

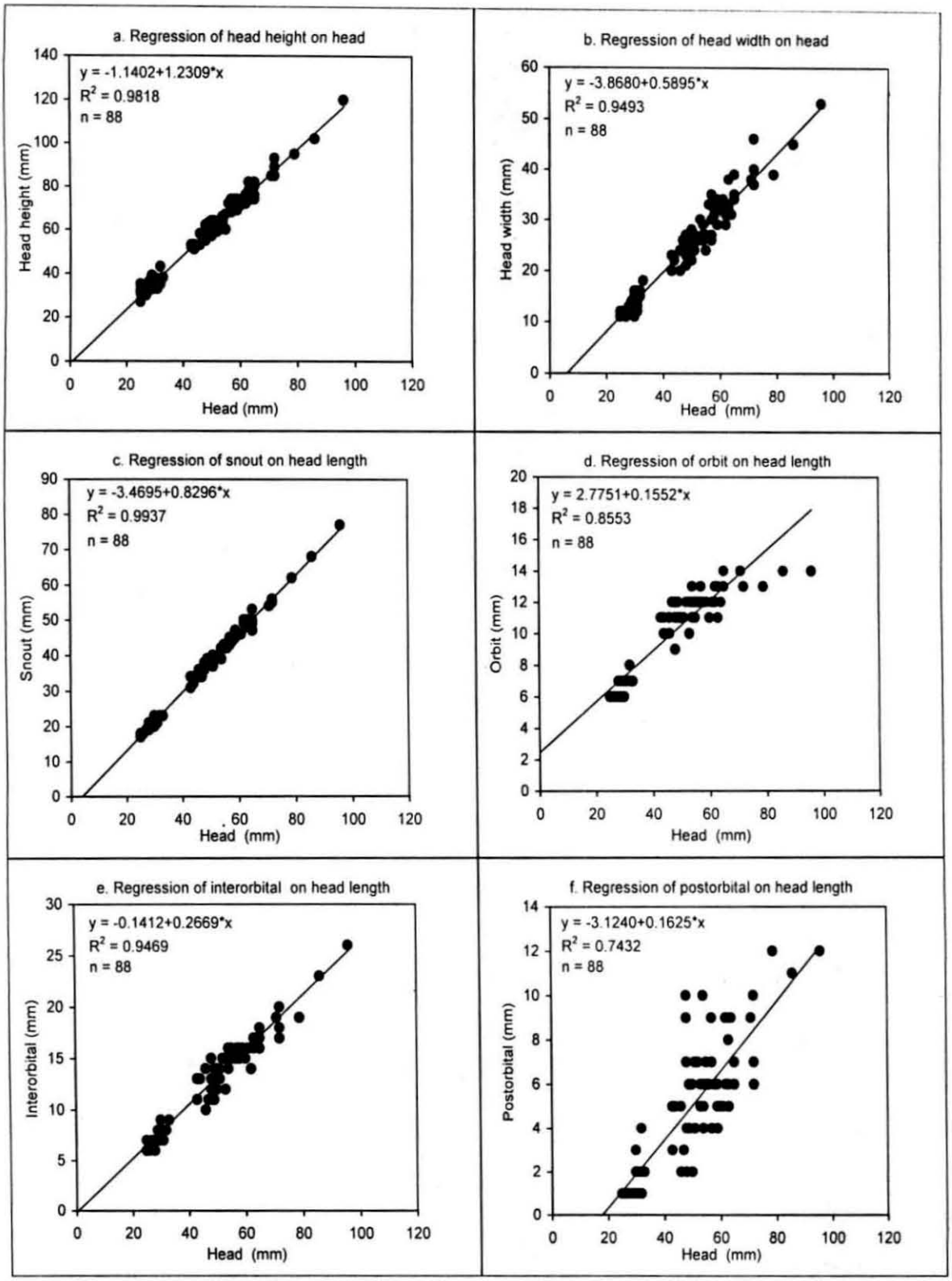


Figure 66. a-f. Regression of different head diemnsions on head in *Sufflamen fraenatus* from south west coast of India

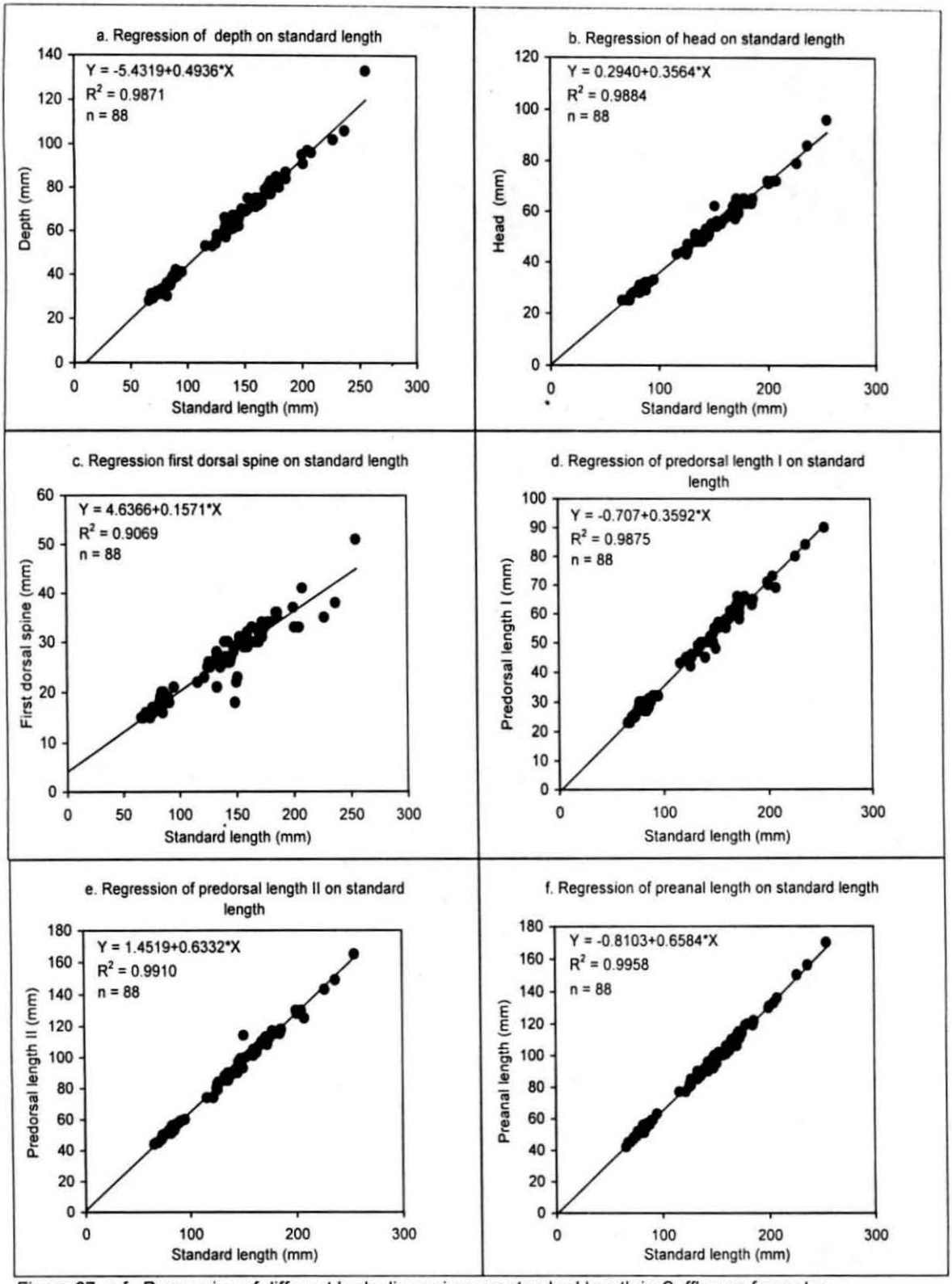


Figure 67. a-f. Regression of different body dimensions on standard length in *Sufflamen fraenatus* from south west coast of India

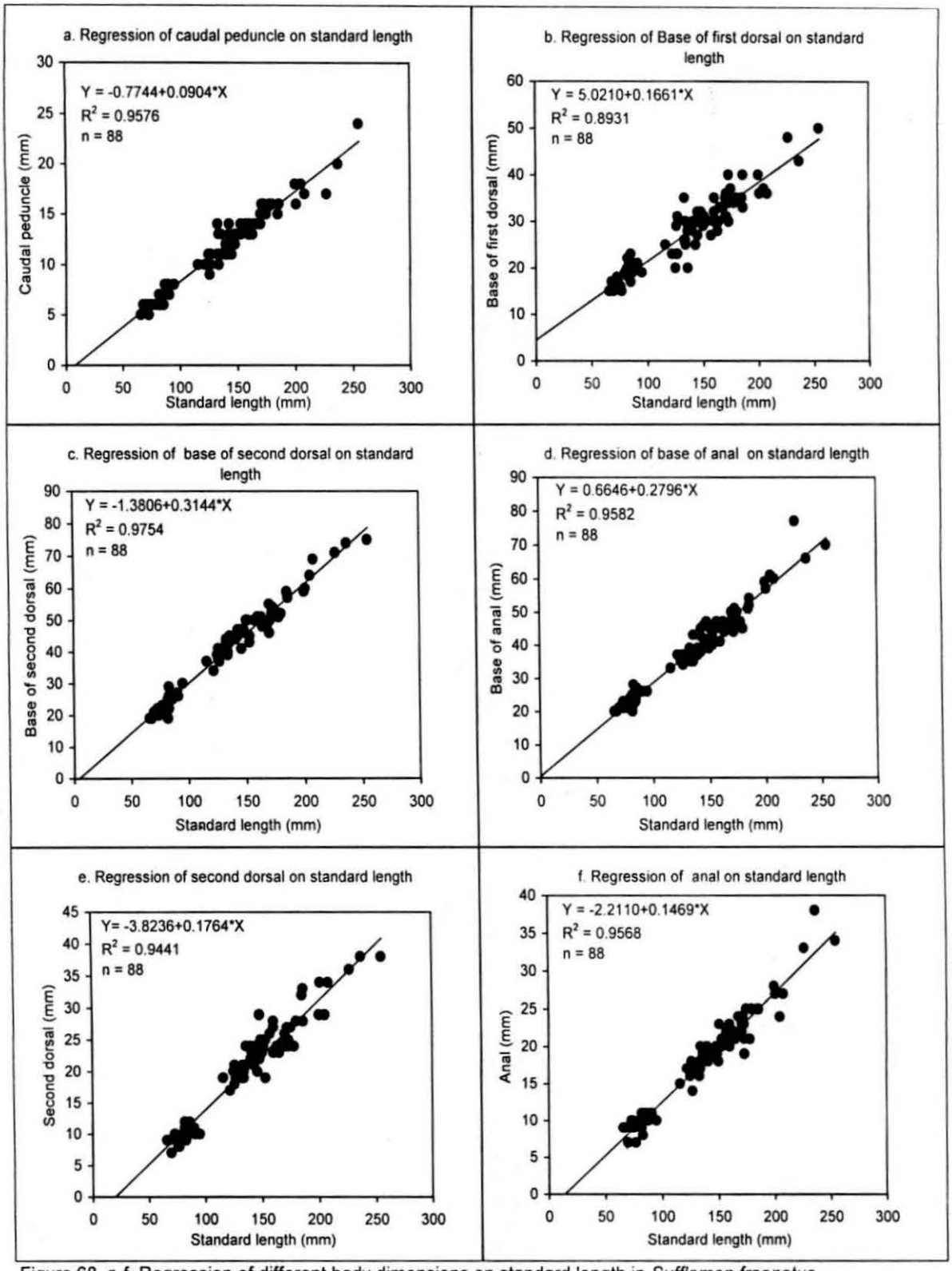


Figure 68. a-f. Regression of different body dimensions on standard length in *Sufflamen fraenatus* from south west coast of India

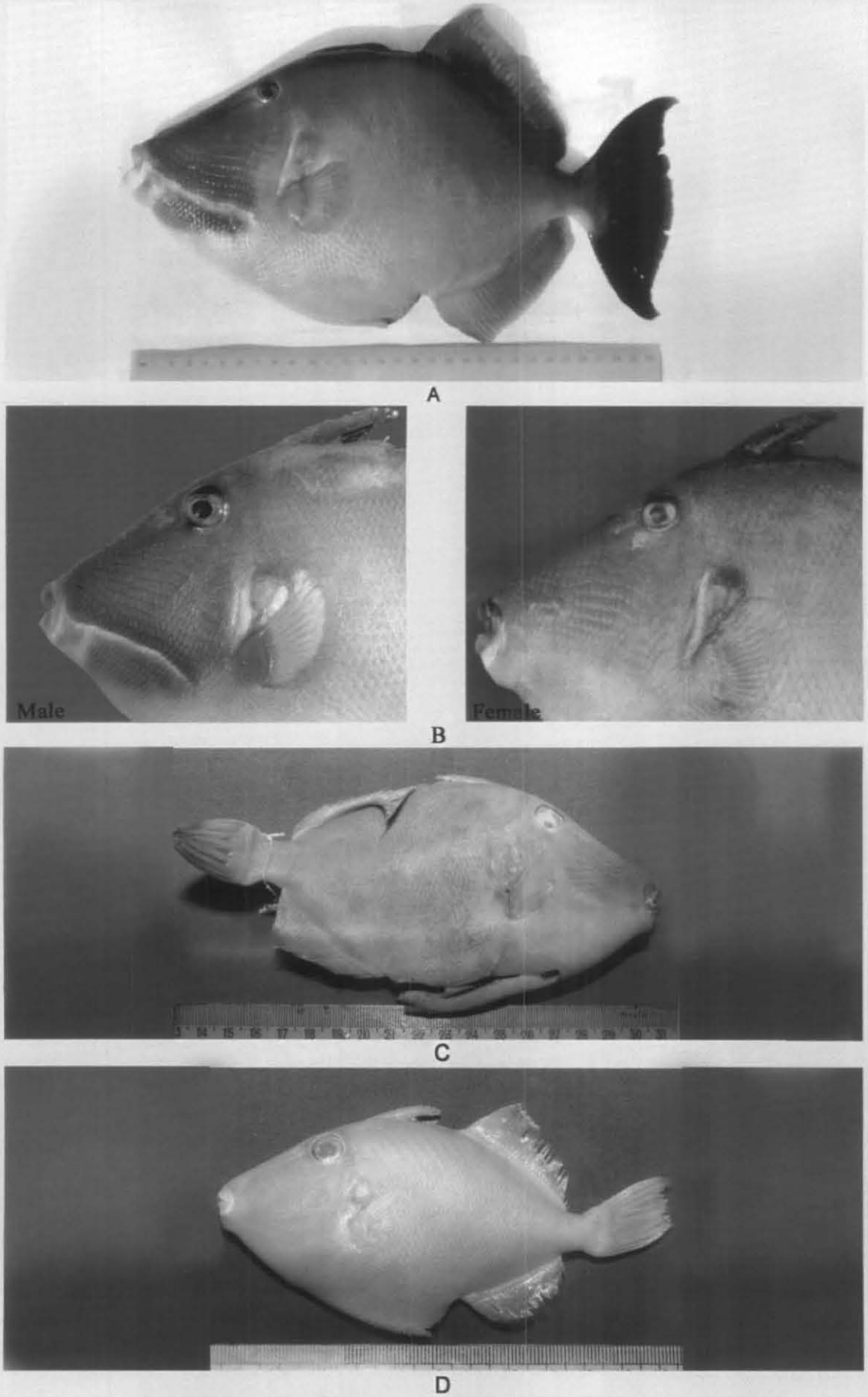


Figure 69. *Sufflamen fraenatus* (Latreille, 1804) : A. From Vizhinjam 334 mm TL, B. Cheek colouration in Male and female, C. From Akyab Bazar ZSI. Reg. No.10622, 182 mm TL, D. From Vizhinjam CMFRI-F 154/441, 120 mm TL.

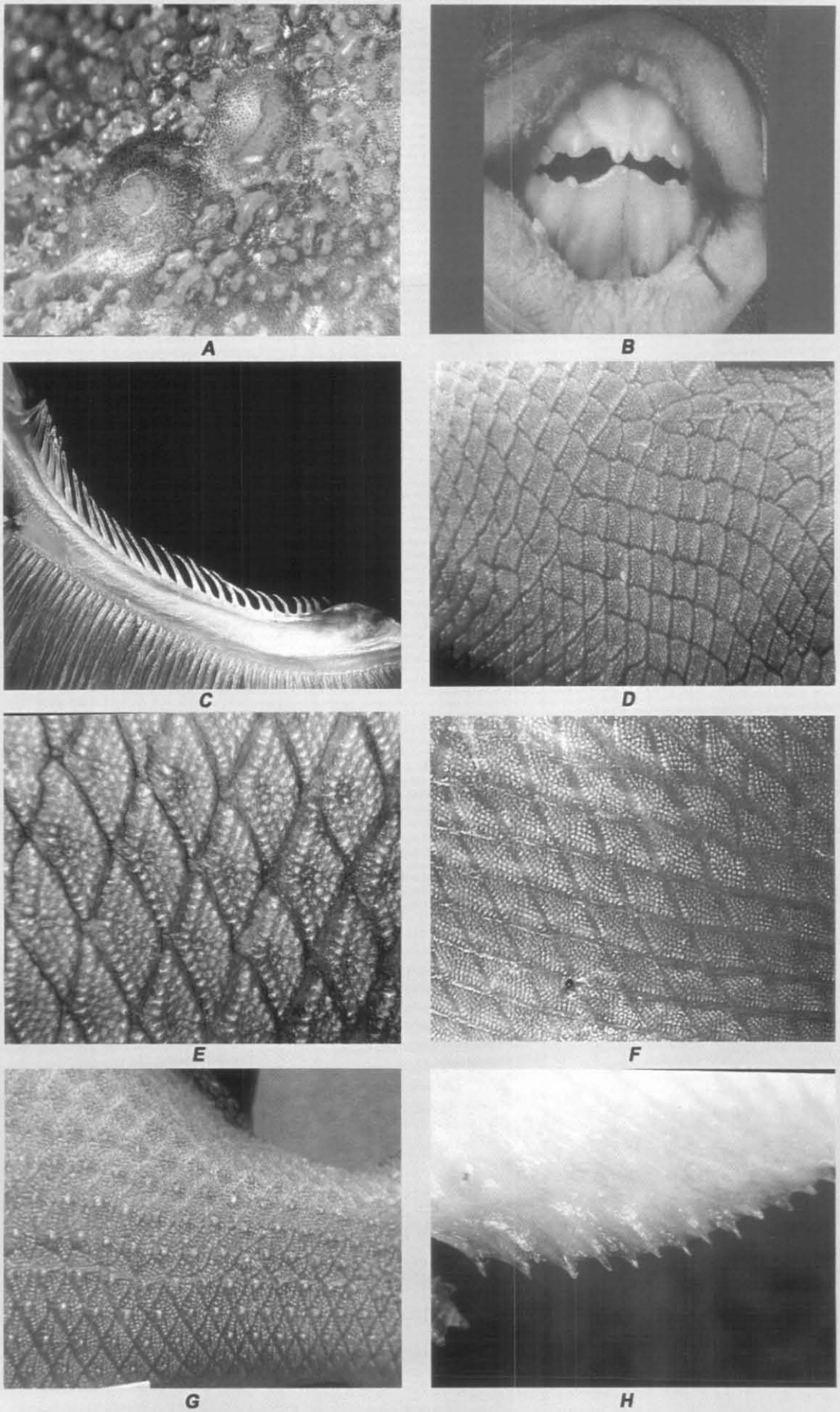


Figure 70. *Sufflamen fraenatus* (Latreille, 1804): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

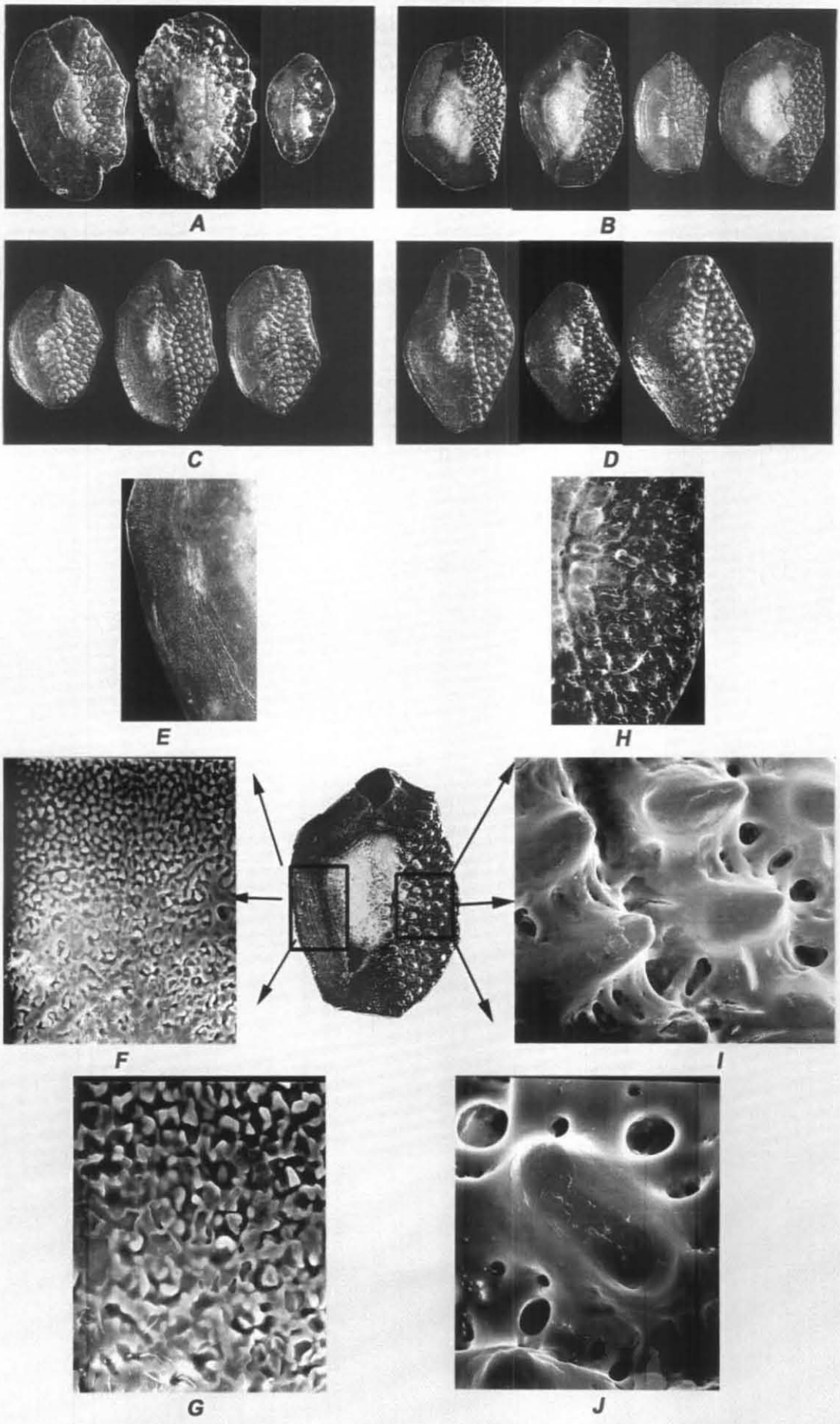
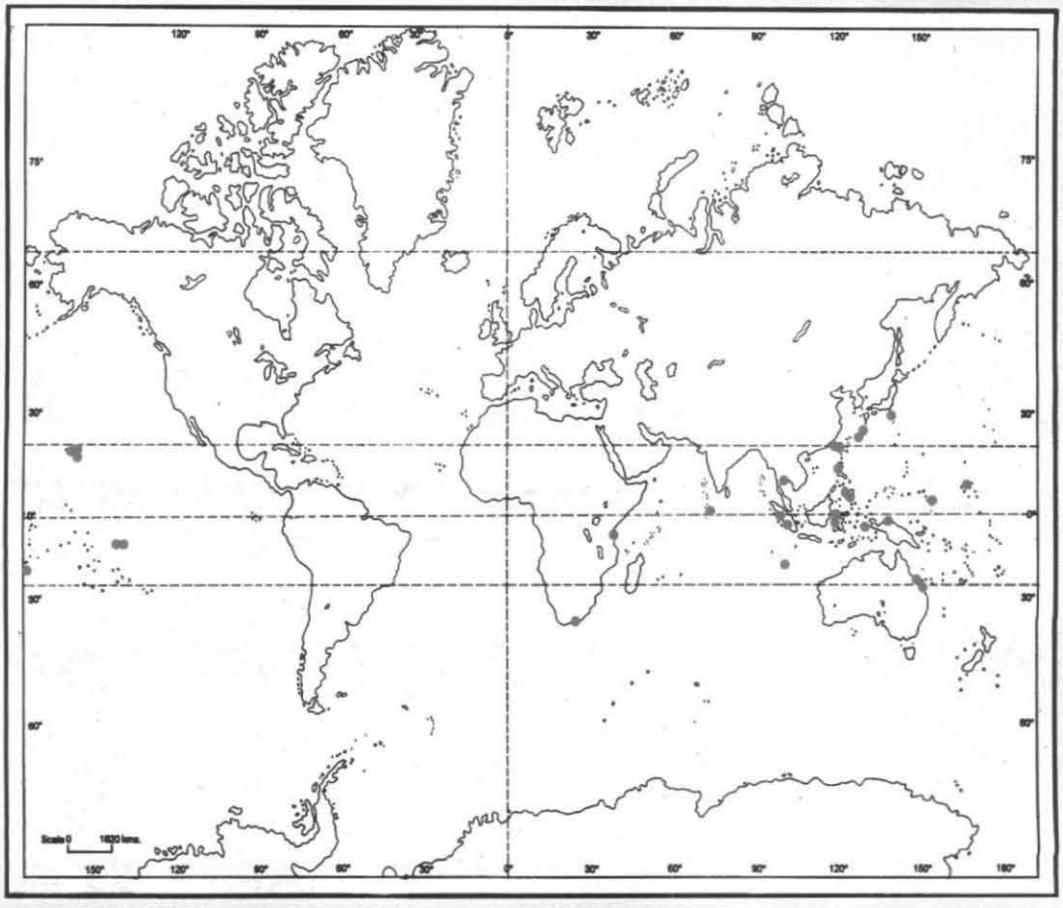
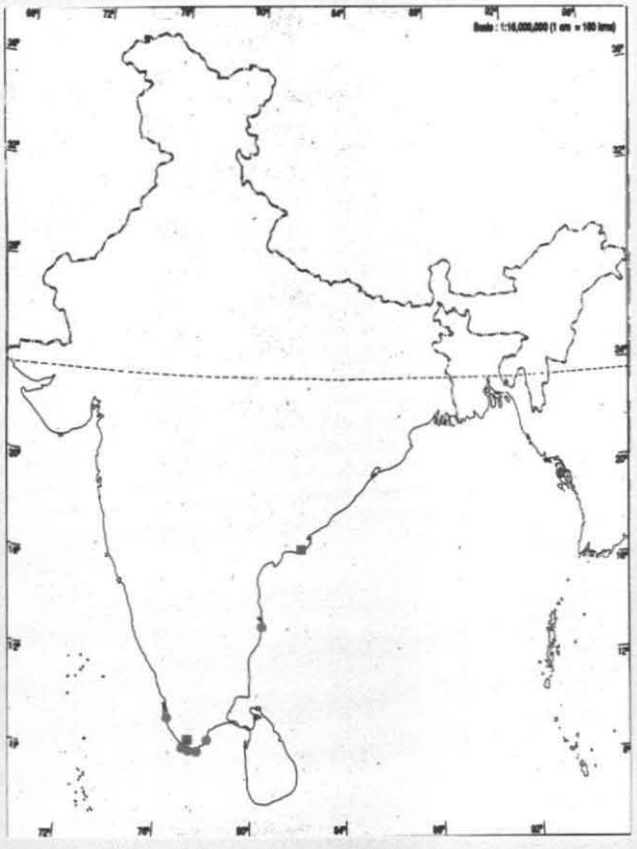


Figure 71. *Sufflamen fraenatus* (Latreille, 1804): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.



A



B

Figure 72. *Sufflamen fraenatus* (Latreille, 1804) : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.8. 2. *Sufflamen chrysopterus* (Bloch and Schneider, 1801)

(Figure 73)

Balistes chrysopterus Bloch and Schneider, 1801, p.466.
Balistes chrysopterus Day, 1878, p.688.
Sufflamen chrysoptera Jones and Kumaran, 1980, p.667. Fig. 568.

Diagnosis

The anterior nasal aperture is dome shaped with a tube at the tip. Scales on cheek rectangular at the anterior, arranged obliquely, diamond at the posterior, arranged vertically. Groove before eye. Body scales have retrose spines. Caudal peduncle equally long and deep with 8–9 rows of antrose spines. Caudal truncate.

Material examined: Two specimens from Kavaratti, (1 male, 1 indeterminate) of lengths 155, 154 mm TL, three specimens from Minicoy, (2 females, 1 indeterminate) of lengths 52, 82, 110 mm TL, (Fig.73.A), two specimens from Lakshadweep, CMFRI Reg. No. F4124/1, of lengths 112,154 mm TL.

Additional material examined: One specimen from Minicoy ZSI Reg. No. F 4124/1. 154 mm TL, (Fig.73.B).

Description

D. III, i, 26–27; P. i, 12; ventral spines. 11–17; A. i, 23-25; C. ii, 10; gill rakers 20- 24; number of scales from origin of second dorsal to base of anal 15–18; lateral line scales 25-60; round the caudal peduncle 11–13.

As percent of head: Head height 111.76–127.27 (118.60); head width 41.18–54.17 (49.82); orbit 15.56–27.41 (22.24); interorbital 23.53–29.17 (26.66); postorbital 2.22–4.44 (2.77).

As percent of standard length: Depth 42.86–46.15 (44.4); head 36.59–40.48 (37.45); snout 26.19–29.27 (28.04); predorsal length (I) 38.46–40.65 (39.50); predorsal length (II) 66.67–71.43 (68.94); preanal length 64.23–69.23 (67.66); postdorsal length (I) 35.71–

41.46 (39.46); postdorsal length (II) 4.76–7.78 (5.85); base of first dorsal 19.51–23.81 (21.04); base of second dorsal 23.81–26.02 (25.20); base of anal 23.81–30.08 (26.55); second dorsal 10.57–13.82 (11.94); anal 9.52–13.85 (11.55); pectoral 10.0–12.31 (11.40); caudal peduncle 7.14–3.23 (8.63).

Body rhomboid. Head profile straight with a prominent chin. Lips thick fleshy and broad, continuous at the corner. Interorbital straight. Groove longer than orbit, narrow at anterior, broader deep towards posterior spiny protuberances present in the groove. First dorsal spine stout, short, blunt, laterally flat and smooth. Minute protuberances at the anterior flat surface, which are round at the bottom, ridges at the mid portion and large ridges at the tip. Nostrils placed in a shallow depression (Fig. 74.A). All the teeth rectangular with the upper side serrated (Fig. 74.B).

Two enlarged rectangular scales arranged opposite to each other and numerous smaller scales arranged in a mosaic fashion in a rectangular area just above the base of pectoral. Gill opening oblique. Gill rakers narrow, hyaline, elongated; with pointed tips and minute blunt protuberances towards the inside (Fig. 74.C). Second dorsal and anal fin are short and have a convex profile. Pectoral round.

The scales on cheek have ridges and round protuberances arranged in 4–5 vertical rows (Fig.74. D & Fig.75.A). Body scales have blunt retrose spines arranged in 3-6 vertical rows (Fig.74. E & Fig.75.B). The ultra structure of the anterior portion of the body scale has irregular shaped projections (Fig. 75. E –G) and the posterior portion has blunt retrose spines (Fig. 75. H - J). The scales on abdomen are rectangular with ridges and blunt retrose spines arranged in 3-5 oblique rows (Fig.74.F & Fig.75.C). Caudal peduncle laterally elliptical. Scales on caudal peduncle are of two types i) scales with an antrose spine at the anterior middle and 3-5 vertical rows of blunt retrose spines and ridges ii) scales have blunt retrose spines and ridges arranged in 3-6 vertical rows (Fig. 74.G & Fig.75.D).

Ventral flap broad at the anterior and narrow posteriorly. Ventral spines 11–17 are short, pointed, and transparent (Fig.74.H).

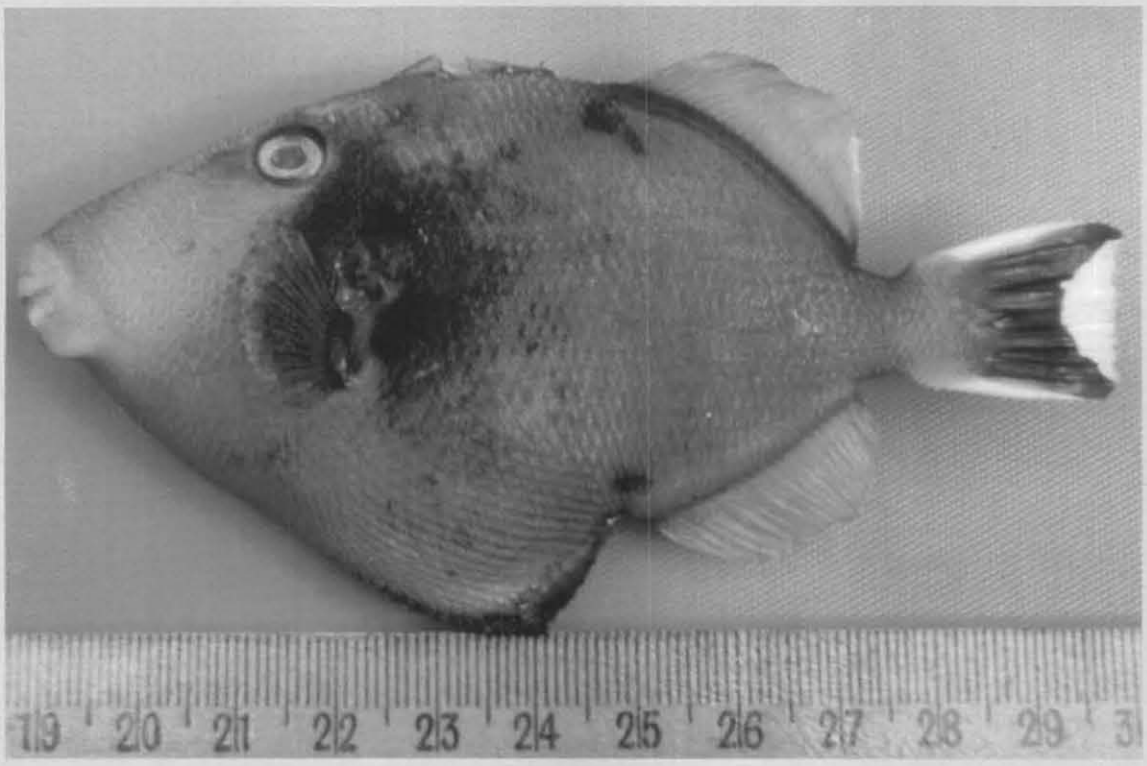
Colour

Fish dark reddish blue, with yellow lips. First dorsal dark brown. Second dorsal and anal light yellow to brown, translucent. Caudal brown with the edges white a white crescent at the posterior. Just above the lips a blue band which extends from corner of mouth to the pectoral base across cheek. A narrow bright blue band originates behind the eye and meets the pectoral base (Fig.73.A).

Colour of the preserved specimen: The whole fish is brown caudal has a white crescent at the posterior edge (Fig.73.B).

Distribution

Red Sea (Ruppell, 1835); Solor, Ambonia, New Guinea, Priaman (Sumatra), Java, Nias, Celebes, Sangi, Obi-Mayor, Ambonia, Banda, Bulukomba, Manado (Celebes) (Bleeker, 1853, 1857, 1859,1860); Malay Archipelago (Day, 1878); Fate, New Hebrides (Vanuatu) (Seale, 1906); East cove, Fuga Island (Philippines) (Jordan and Richardson, 1908); Island Binongka, Banda Archipelago (Max Weber, 1913); Jamillo, Batangas; Iba, Zambales; Monja Islands, Sasi (Philippines) (Herre, 1924); Daikuma (Amami-Oshima) (Japan) (Schmidt, 1930); Zamboanga (Mindanao) (Gitlay, 1933); Ponape, Nanyo (Japan) (Herre, 1939); Brock and Mau, Bikini Atoll, Rongelap Atoll, Kieshiechi Island (Marshal Islands) (Schultz, 1966); Yakushima Island, Satsunan Islands, Ishigaki Island, Ryukyu Islands, Okinawa Island (Matsuura, 1980); Maldives (Jones *et al.*, 1981); Sesoko Island (Japan) (Kuwamura, 1991); Thailand (Nateewathana, 1993); Wanlitung (Taiwan) (Shoa *et al.*, 1994); Cocos Island (North Western Australia) (Allen and Smith 1996) (Fig. 76.A & B).



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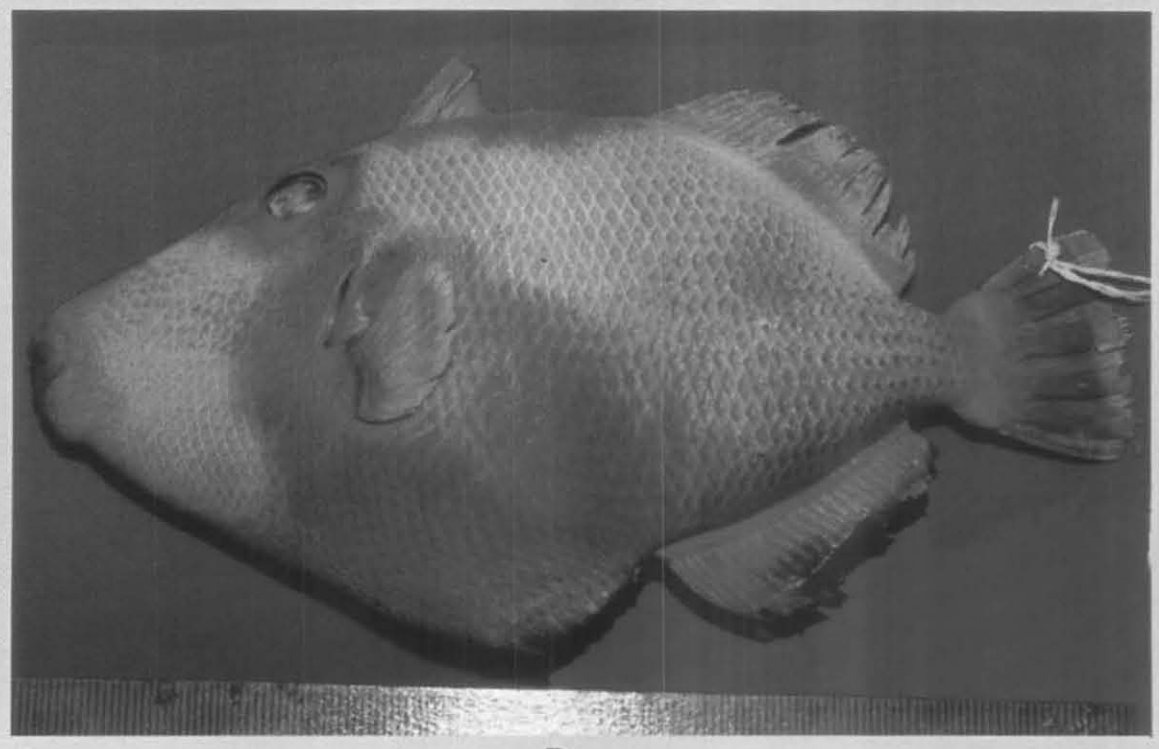


B

Figure 73. *Sufflamen chrysopterus* (Bloch and Schneider,1801) : A. From Minicoy 110 mm TL, B. ZSI Reg. No. F.4124/2 154 mm TL.

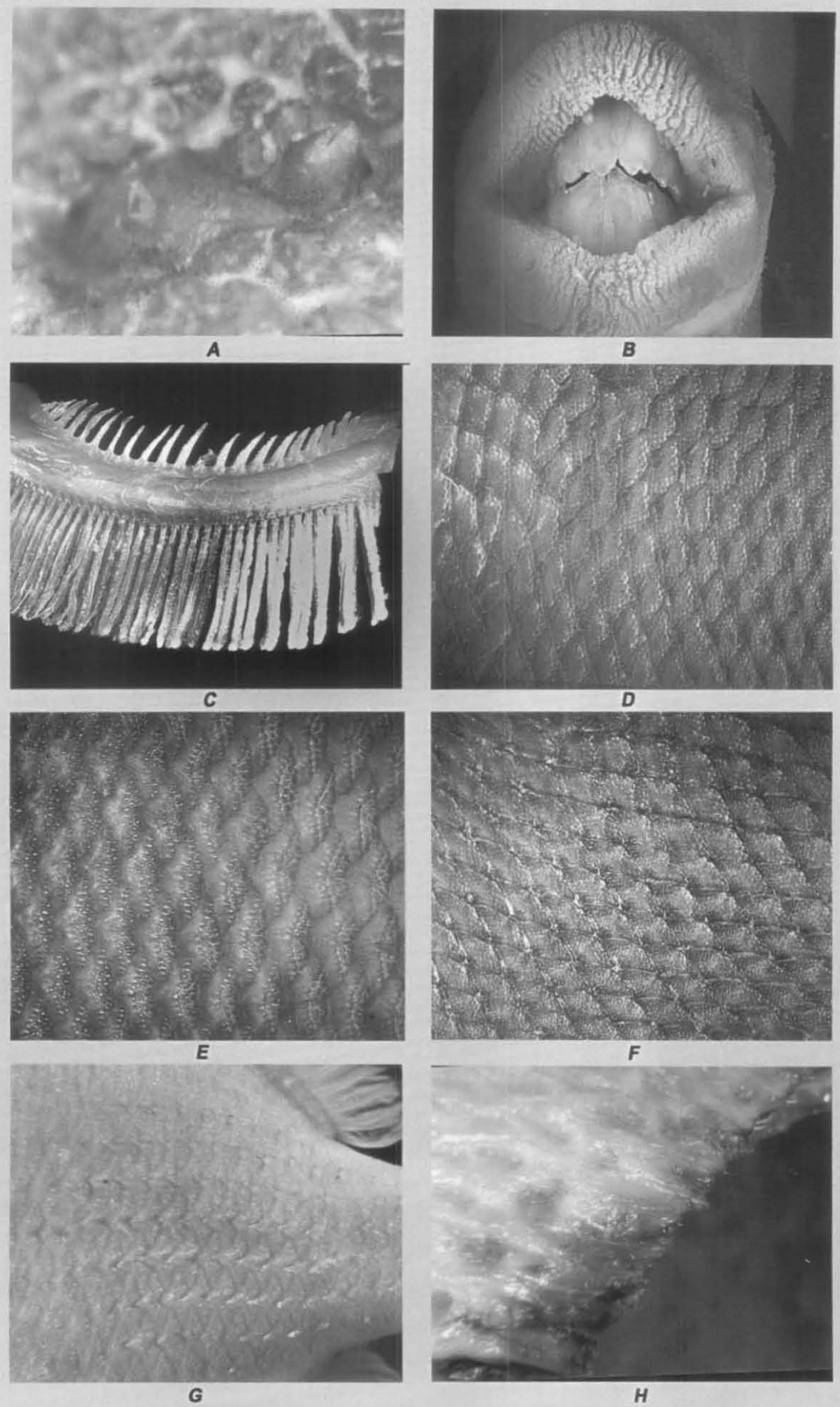


Figure74. *Sufflamen chrysopterus* (Bloch and Schneider, 1801): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

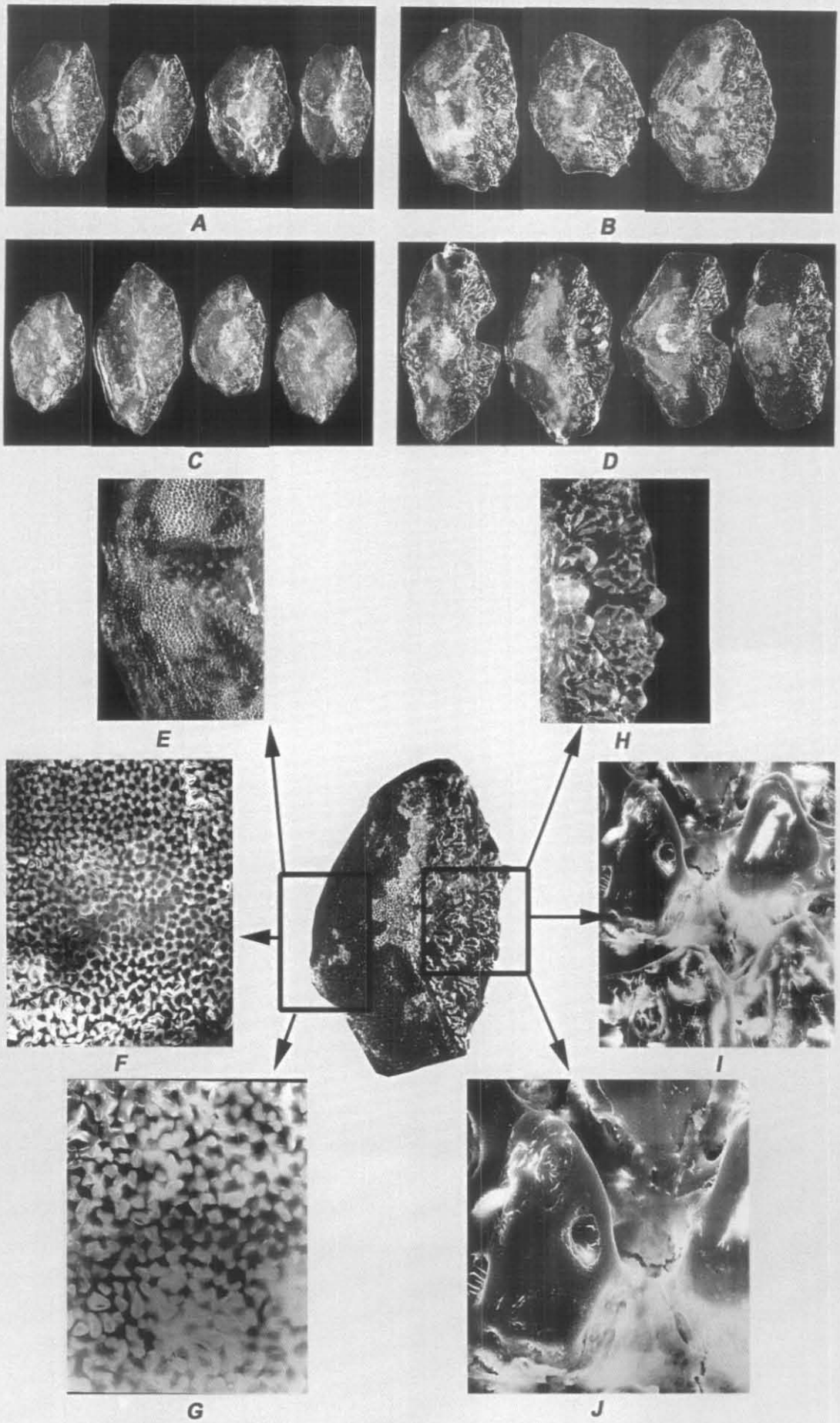


Figure 75. *Suffiamen chrysopterus* (Bloch and Schneider,1801): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.

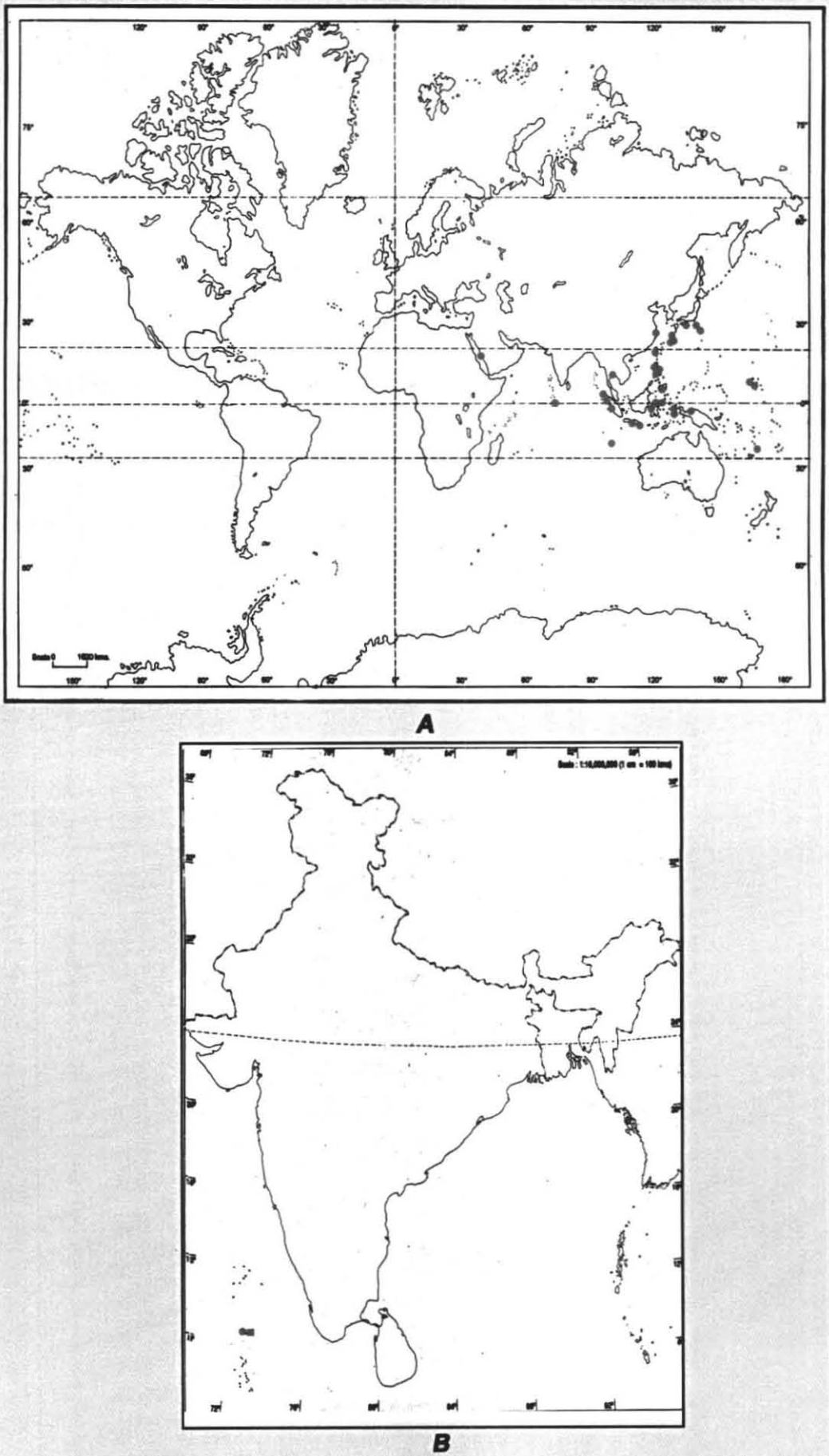


Figure 76. *Sufflamen chrysopterus* (Bloch and Schneider,1801): A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

2.5.9. *Abalistes* Jordan and Seale, 1906

(Type species *Balistes stellaris* Bloch and Schneider, 1801 = *Balistes stellatus* Lacepede, 1798)

Diagnosis

Anterior nostril funnel shaped. Scales on cheek rhomboid, arranged in vertical rows, have round protuberances. Grove before eye. Body scales with spherical and round protuberances and ridges. Caudal peduncle depressed dorso-ventrally, longer than deep. Caudal peduncle has 3-4 rows of ridges. Caudal double lunate.

2.5.9.1. *Abalistes stellatus* (Lacepede, 1798)

(Figure 80)

Balistes stellatus Lacepede, 1798, p. 350.
Balistes stellatus Day, 1878, p.687.

Material examined: Ten specimens from Colachel, (2 males, 8 females) ranging from 158 to 411 mm TL, (Fig.80.A), seven specimens from Vizhinjam, (2 males, 5 females) ranging from 201 to 287 mm TL, (Fig.80.C).

Additional material examined Eleven specimens from Tuticorin, (7 males, 4 females) ranging from 260 to 425 mm TL (Fig.80), 2 specimens from Madras, ZSI. Reg. No. 2254 and 2717, of lengths 135, 166 mm TL (Fig.80.D & F) collected by Dr. Day, one specimen from Bay of Bengal, ZSI. Reg. No. F603/2, of length of 246 mm TL, (Fig. 80.E).

Description

D. III, i, 25-26; P. i, 13-14; ventral spines 5-13; A. i, 23-25; C. ii, 10; gill rakers 29-33; number of scales from origin of second dorsal to base of anal 14-18; lateral line scales 29-68; scales round the caudal peduncle 9-12.

As percent of head : Head height 106.82–123.44 (116.83); head width 50.0–62.30 (54.24); orbit 18.02-28.26 (22.93); Interorbital 29.23–39.13 (32.69); postorbital 6.45–16.98 (12.15). The regressions of different head dimensions on head are given in figure 77.

As percent of standard Length: Depth 37.10–42.38 (39.70); head 32.32–36.72 (34.16); snout 22.14–25.20 (24.49); predorsal length (I) 31.07–37.14 (33.63); predorsal length (II) 60.10–65.04 (62.76); preanal length 60.34–65.14 (62.37); postdorsal length (I) 37.29–43.05 (39.65); postdorsal length (II) 8.56–11.66 (9.85); base of first dorsal 23.32–28.97 (26.63); base of second dorsal 25.7–30.81 (27.71); base of anal 24.16–30.60 (27.75); second dorsal 9.09–13.01 (11.33); anal 9.48–12.50 (10.57); pectoral 7.72–10.40 (9.18); caudal peduncle 3.95–5.30 (4.49). The regressions of different body dimensions on standard length are given in figure 78 & 79.

Body oval, head profile, convex dorsally, straight ventrally, chin prominent. Lips thick, cylindrical. Inter-orbital straight and broad. Groove before eye, deep longer than orbit, directed downwards. Nostrils, placed in a shallow depression with the anterior nostril (funnel shaped) having curved edges and a small lobe towards the posterior (Fig. 81.A). First dorsal spine, cylindrical, slender, pointed. Third spine ¼ the length of first spine. All the teeth are conical with pointed tip (Fig.81.B).

Enlarged scales (rectangular with edges round), five to six, arranged in an oval area at the base of pectoral. In 200-300 mm length groups enlarged scales are fused together, in 80–150 mm length groups the enlarged scales are attached on a flexible membrane. The gill rakers are hyaline, elongated with pointed tips (Fig.81.C). Second dorsal and anal, rectangular, with serrated edge. Pectoral round.

Scales on cheek have 3-8 vertical rows of round protuberances (Fig.81. D & Fig. 82.A). Body scales have a large spherical protuberance at the anterior middle. Ridges from the anterior most row followed by round protuberance arranged in 2-7 vertical rows (Fig.81. E & Fig.82.B). The ultra structure of the anterior margin of the body scale has

ridges arranged in rows (Fig.82. E–G) and the posterior margin has first row of ridges and round protuberances (Fig.82. H-J). Scales on abdomen rectangular or rhomboid, arranged obliquely and have ridges (Fig.81. F & Fig.82.C). Scales on caudal peduncle have a transverse ridges at the centre and 3 -5 horizontal rows of round protuberance (Fig.81. G & Fig. 82.D).

Ventral flap wide supported by many pointed, elongated, hyaline, slender ventral spines. Two rows of retrose spines arranged on the flap (Fig. 81. G). Pelvic spine short, moveable, broad, cylindrical decorated with spinules. Few larger spinules are arranged at the anterior portion directed backwards and some are also arranged laterally and posteriorly.

Colour

Dorsally olive green with bluish-white spots, ventrally white, with few narrow green bands obliquely. Iris gold. Upper lip grey and lower lip white. A white streak present on the middle of the body. First dorsal fin with 5-7 parallel yellow bands and a black blotch at the tip. Second dorsal and anal fins have yellow bands which are arranged parallel to body, pectoral fin yellow. Four white blotch, first blotch anterior to first dorsal fin, second blotch between first and second dorsal fin, third blotch exactly at the middle of second dorsal fin, fourth blotch on caudal peduncle. Caudal fin brown.

Colour of the preserved specimens: The whole body golden brown, with prominent white spots dorsally. Four white blotches, one at the origin of the first dorsal, second blotch between first dorsal and second dorsal, third blotch at the middle of the second dorsal, fourth blotch on the caudal peduncle. White streak at the lateral middle. Fins brown.

Distribution

Mauritius (Lacepede, 1798); Indian Seas (Bloch and Schneider, 1801); East Indies, New Ireland, Pacific Ocean, Eastern Asia, Singapore, Batavia (Java), Makassar

(Celebes), Coromandelia (India), Ambonia (Ceram) (Bleeker, 1852, 1853, 1857); Von (Java) (Kner, 1865); Zanzibar (Gunther, 1866); Mauritius, Ceylon, Singapore, Amboynas, China Sea, West Australia, Hope Island (North east Australia), Louisiade Archipelago (Gunther, 1870); Kandavu (Fiji Island) (Gunther, 1876); Andaman (Day, 1878); Thailand (Nateewathana et al., 1993); Malampaya Sound, Basilan, Estancia, Panay (Philippines) (Herre, 1924); Naha – Okinawa Island, Ryukyu Island, Itoman-Okinawa Island (Japan) (Matsuura, 1980); Trucial, Qatar coast (Katsuzo Kuronuma and Abe, 1986) (Fig.83.A & B).

Remarks

The Body shape of the figure in Histoire Naturelle of Lacepede (1798) (plate 15, figure1) does not exactly represent the species but gives a rough shape of the fish. Few white dots are seen scattered dorsally but lacks the prominent four white blotches and a white streak at the middle of the body. The caudal is shown as forked but this fishes from Indian seas have double lunate caudal.

Bleeker in his Atlas Ichthyology (1865) has brought out colour patterns of this fish in minute details. But few of the bands, which originate below eye and at the corner of the mouth was not present in the specimens caught from our region.

Taxonomic note: The genus is monotypic and the description of genus given by Jordan and Seale (1906) and species description of Bloch and Schneider (1801) conform to the specimens of this species (this species is rare) collected from the southeast and west coast of India.

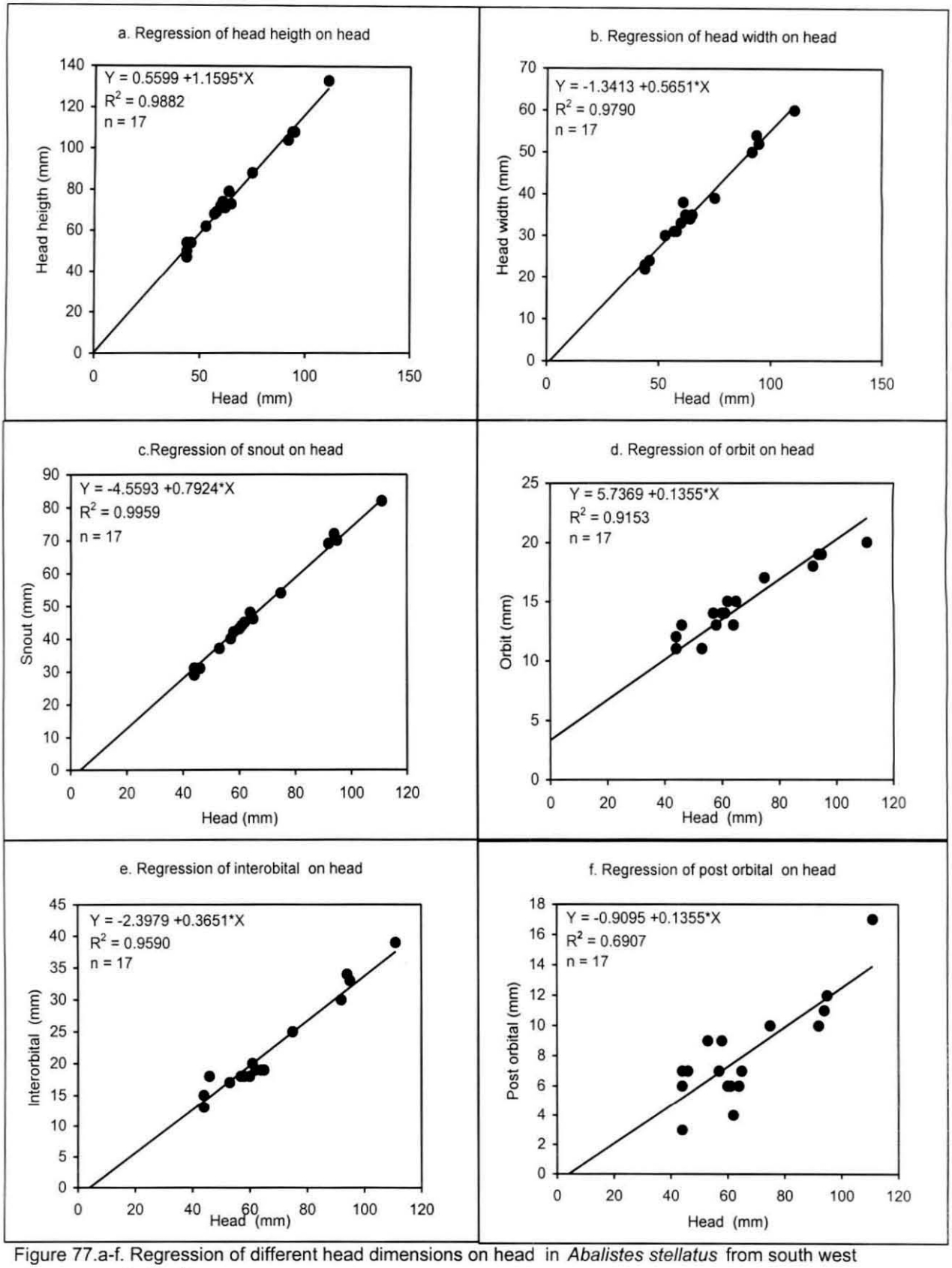


Figure 77.a-f. Regression of different head dimensions on head in *Abalistes stellatus* from south west coast of India.

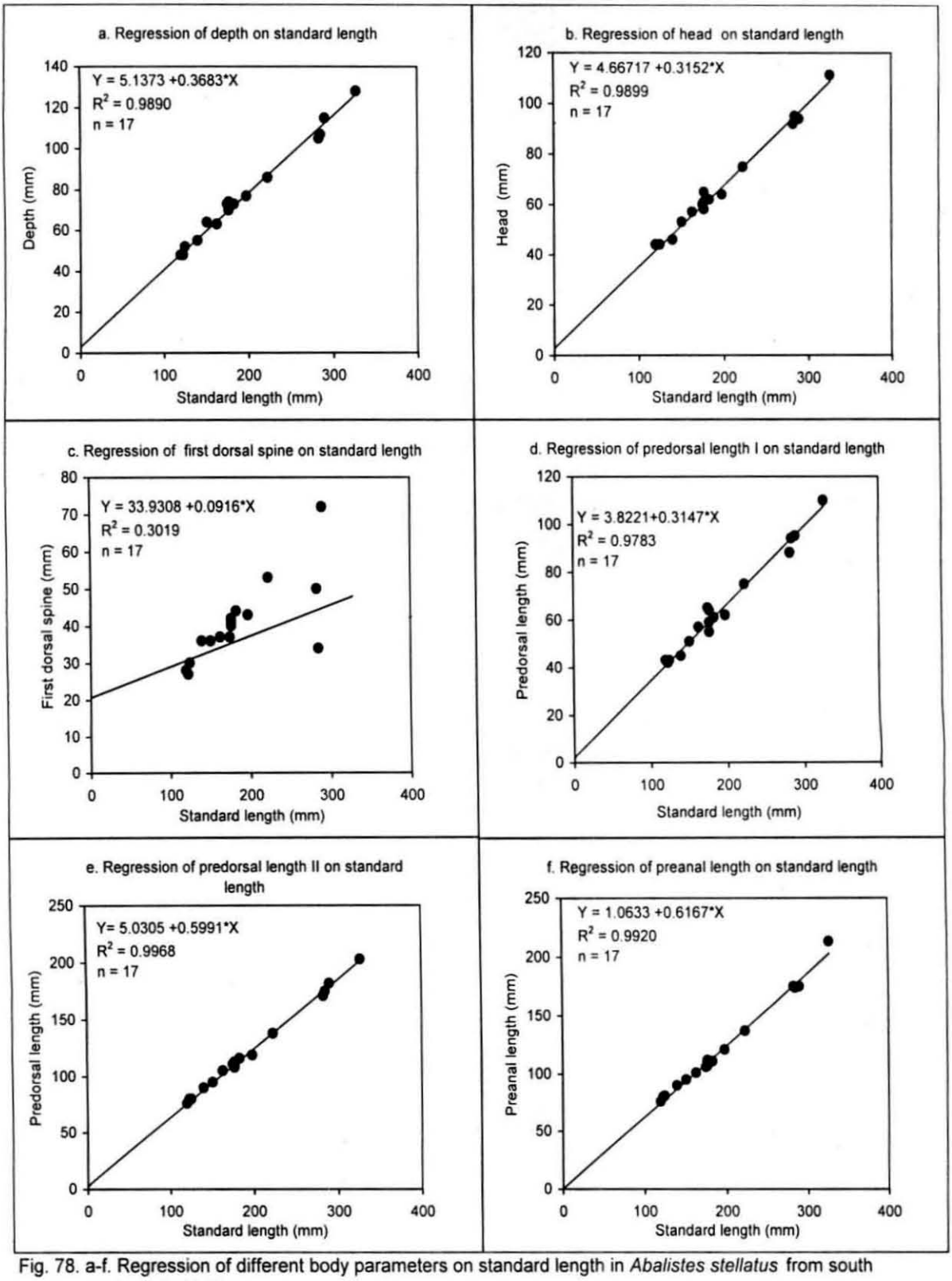


Fig. 78. a-f. Regression of different body parameters on standard length in *Abalistes stellatus* from south west coast of India

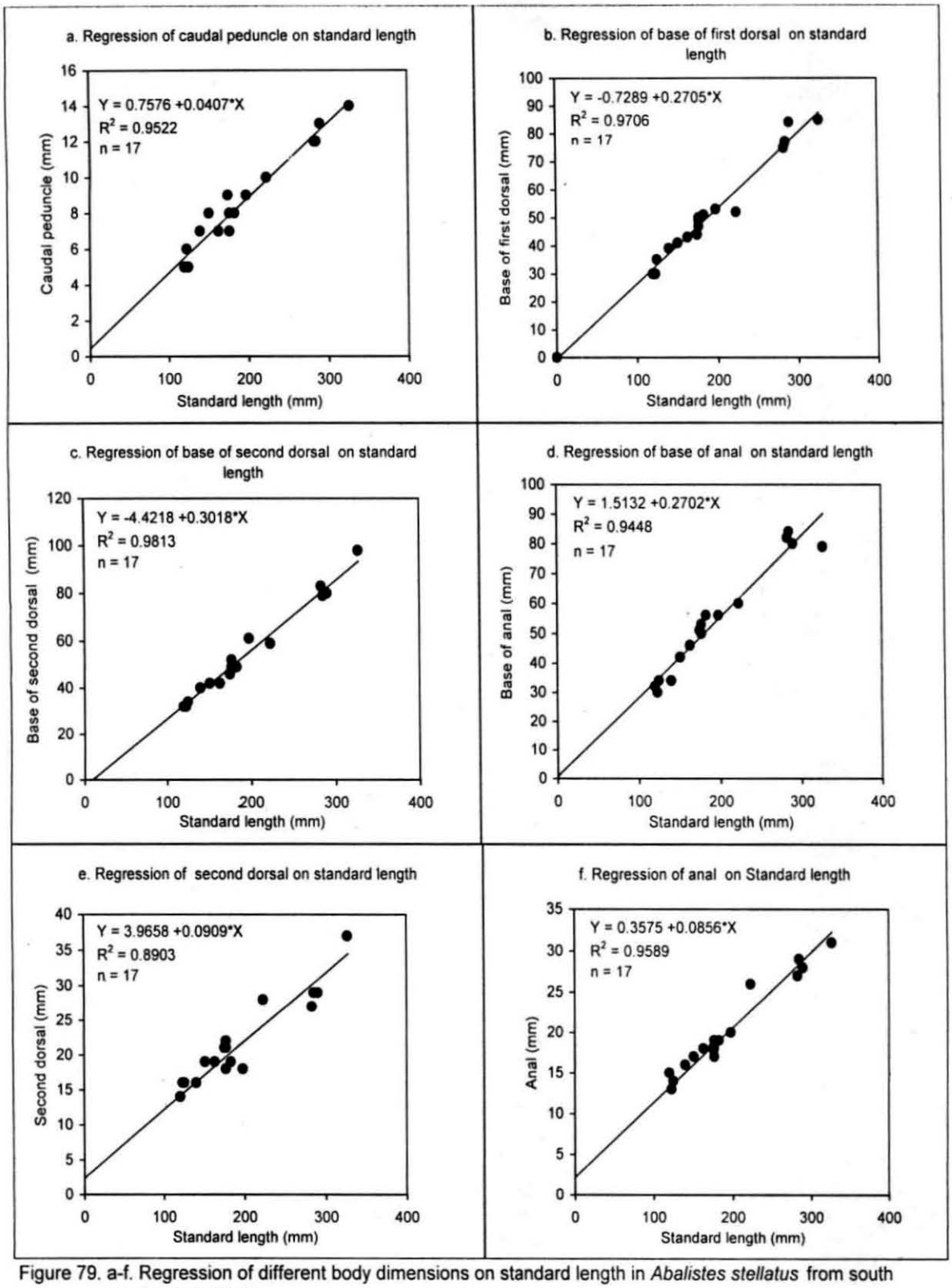


Figure 79. a-f. Regression of different body dimensions on standard length in *Abalistes stellatus* from south west coast of India

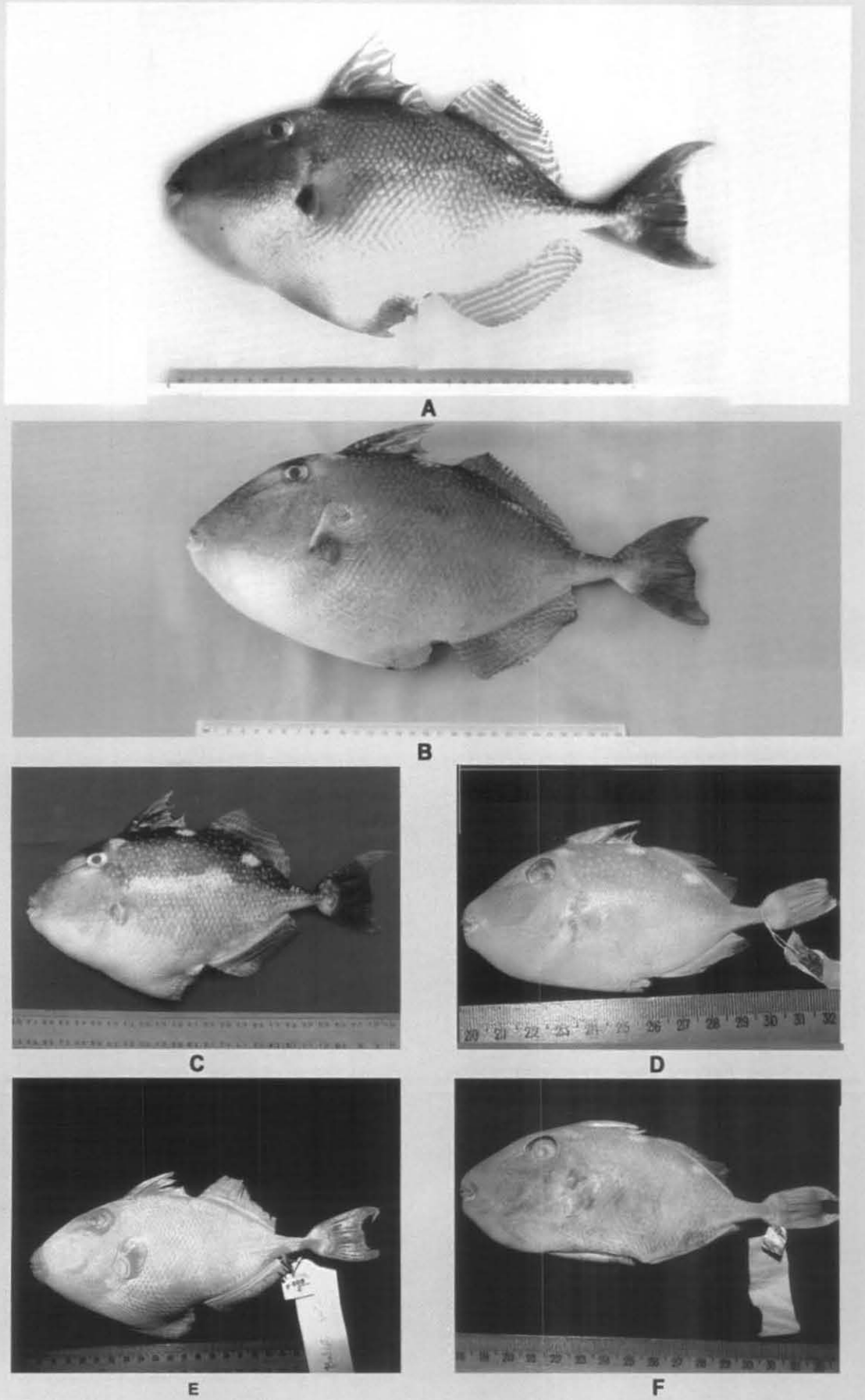


Figure 80. *Abalistes stellatus* (Lacapede, 1798) : A. From Colachel 380 mm TL, B. From Tuticorin 345 mm TL, C. From Vizihinjam 228 mm TL, D. From Madras ZSI. Reg. No. 2717, 135 mm TL, collected by Dr. F. Day, E. From Bay of Bengal ZSI Reg. No. F. 603/2, 246 mm TL, F. From Madras ZSI Reg. No. 2254, 166 mm TL, collected by Dr. F. Day.

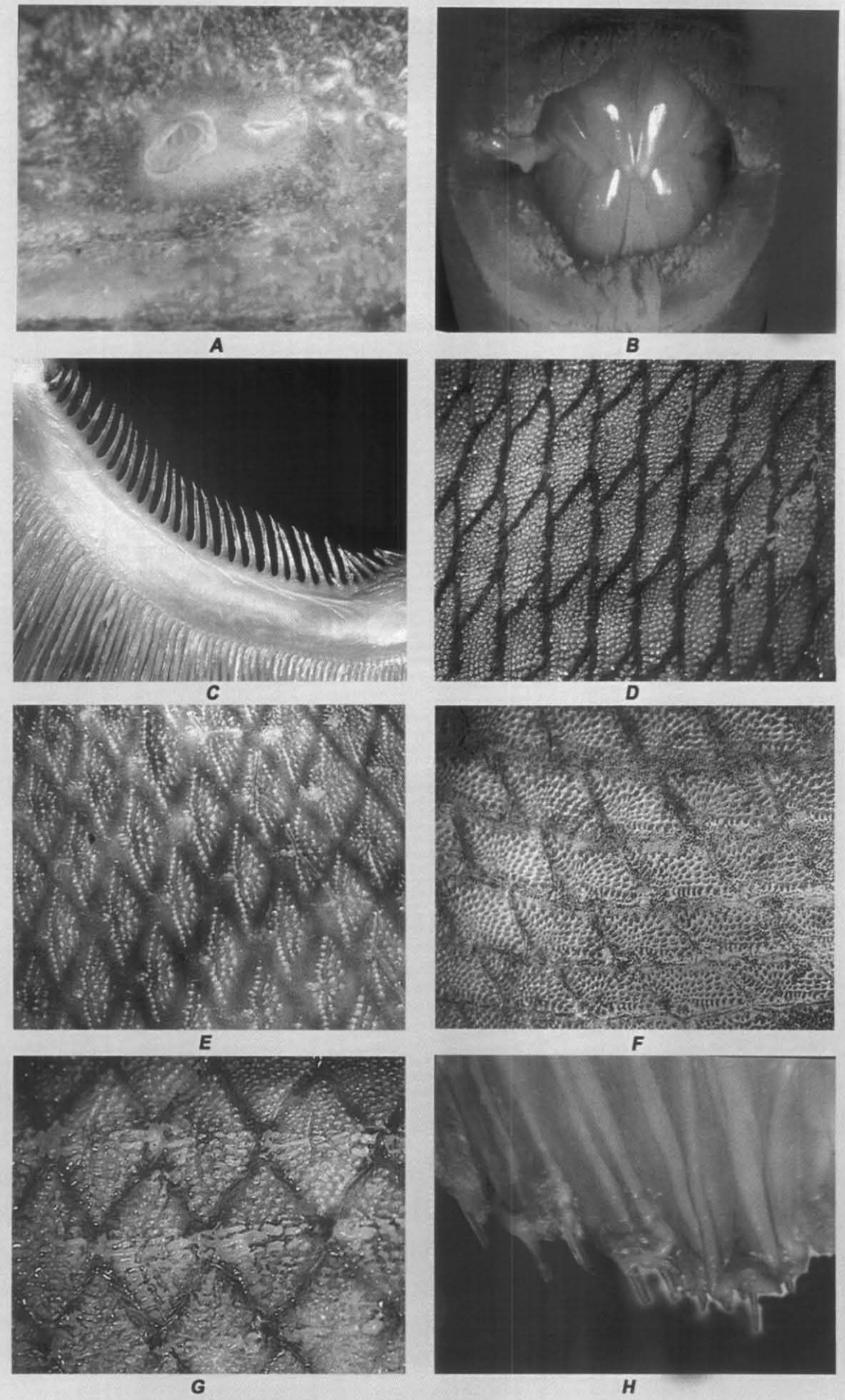


Figure 81. *Abalistes stellatus* (Lacepede, 1798): A. Nasal apertures, B. Teeth, C. Gill rakers, D. Scales on cheek, E. Body scales, F. Scales on Abdomen, G. Scales on caudal peduncle, H. Ventral spines.

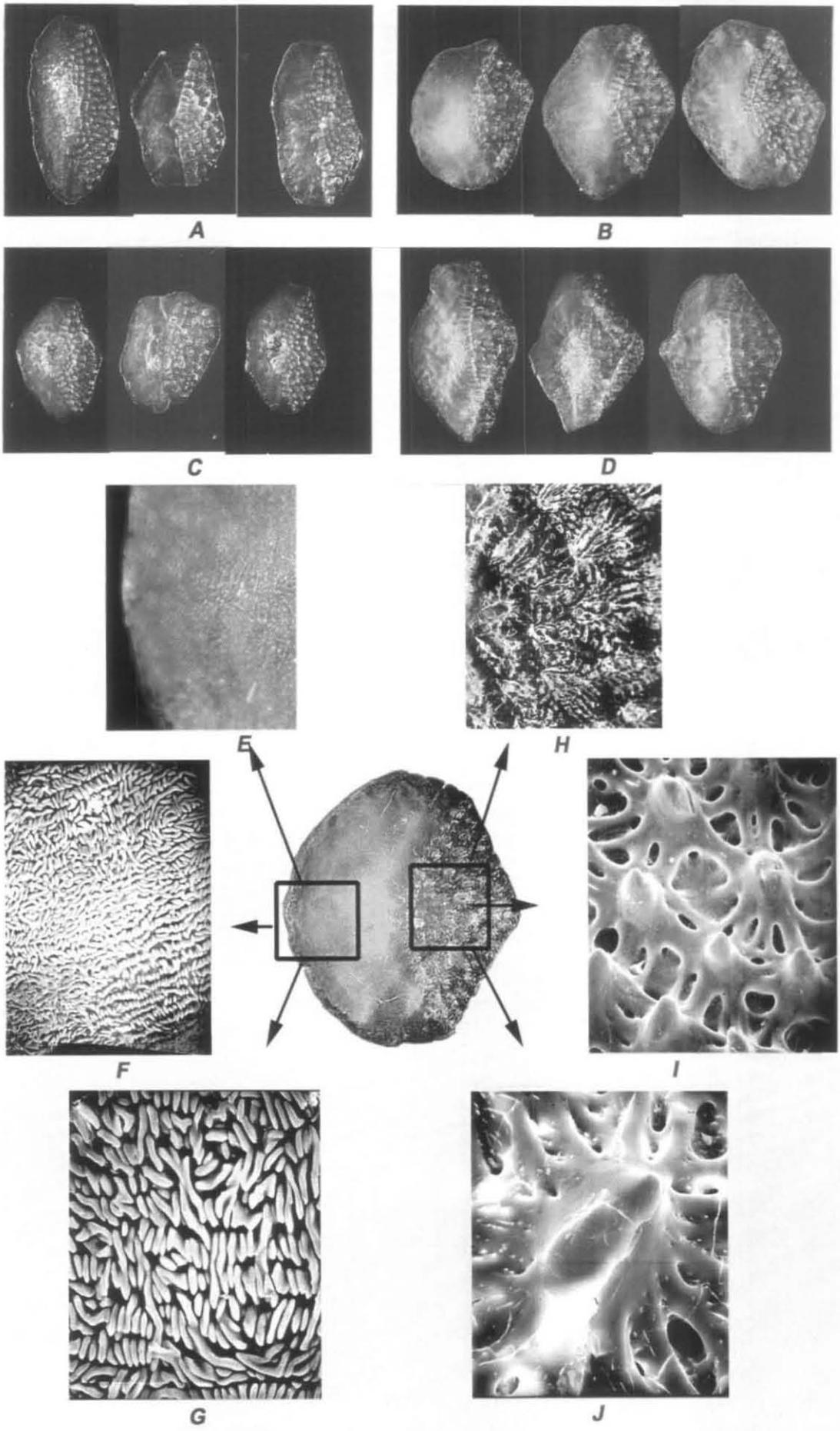
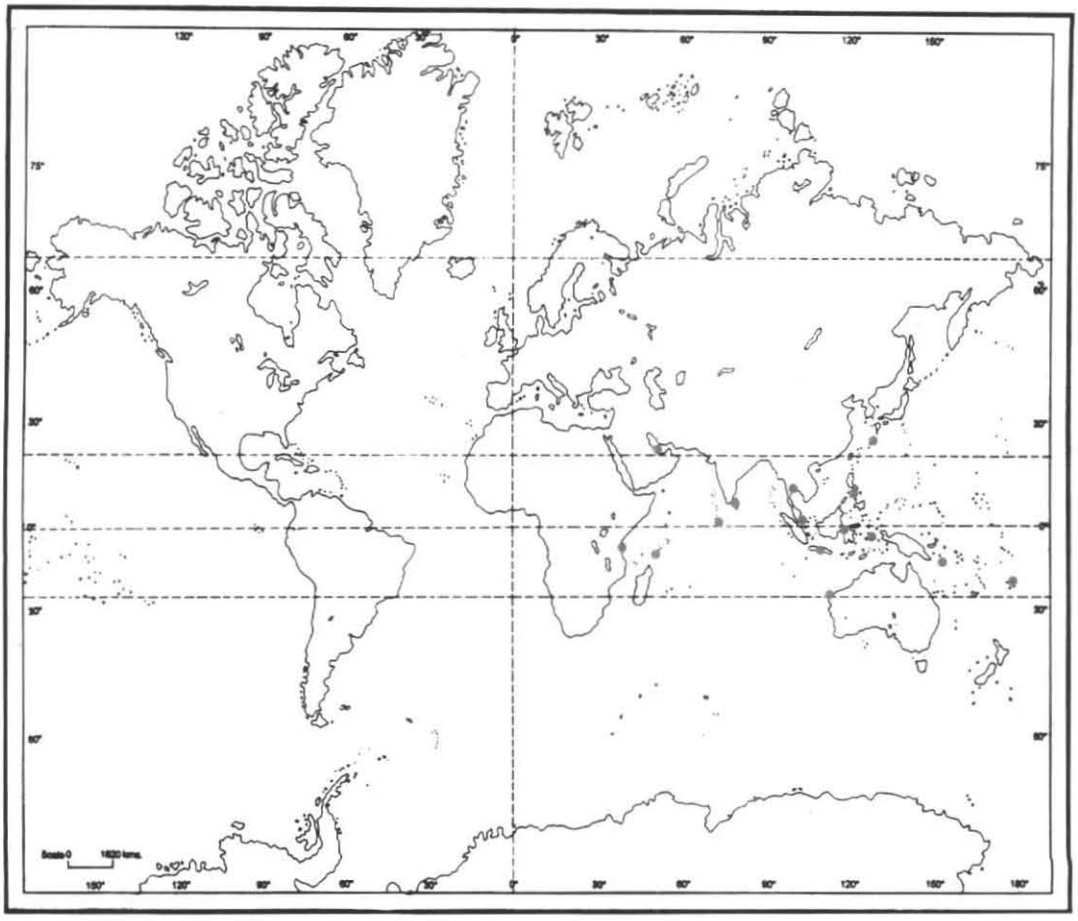
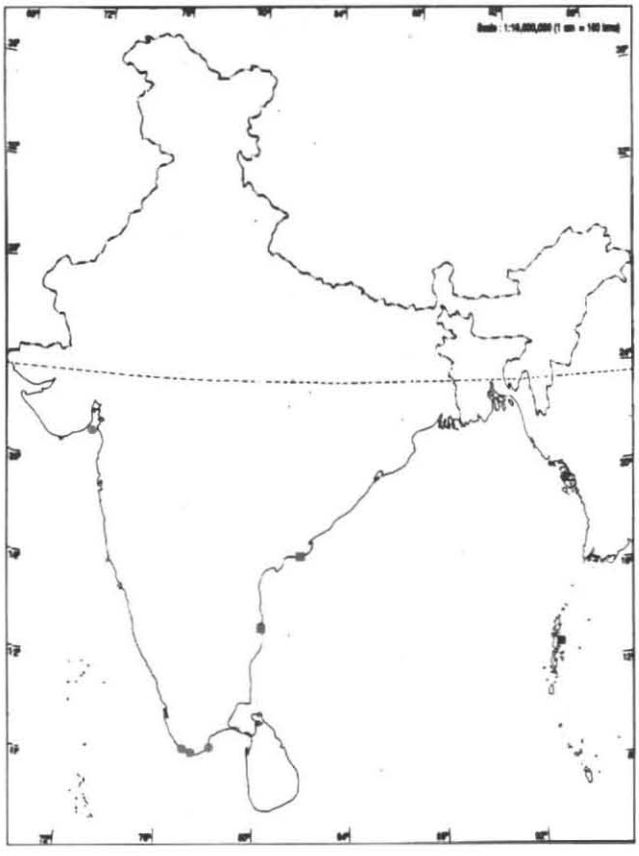


Figure 82. *Sufflamen fraenatus* (Latreille, 1804): A. Scales of cheek, B. Body scales, C. Scales of abdomen, D. Scales of caudal peduncle, E-G. Anterior margin of body scale 40x, 100x, 200x, H-J Posterior margin of body scale 40x,100x, 200x.



A



B

Figure 83. *Abalistes stellatus* (Lacepede, 1798) : A. Distribution in World, B. Distribution in India, ■ on Indian map indicates places from where previous authors made collections, ● on Indian map indicates the places from where specimens were collected.

Table 5 Number of second dorsal rays

S. No.	Species	N	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	X	SD	SE
1	*Abalistes stellatus*	**17**			1	6	10											26.52	± 0.624	± 0.151
2	*Balistapus undulates*	**24**			4	14	6											26.083	± 0.653	± 0.133
3	*Canthidermis maculates*	**23**	7	7	8			1										24.21	± 1.166	± 1.079
4	*Melichthys indicus*	**22**									3	4	11	3	1			32.77	± 1.02	± 0.217
5	*Zenodon niger*	**93**										2	6	38	31	15	1	34.58	± 0.947	± 0.098
6	*Pseudobalistes viridescens*	**15**	1	1	9	3	1											25.133	± 0.915	± 0.236
7	*Pseudobalistes flavimarginatus*	**12**			2	8	2											26	± 0.603	± 0.174
8	*Rhinecanthus aculeatus*	**58**	3	19	29	5	2											24.72	± 0.833	± 0.109
9	*Sufflamen fraenatus*	**89**							2	24	42	16	5					30.97	± 0.878	± 0.093

Table 6 Number of ventral spines

S. No.	Species	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	X	SD	SE
1	*Abalistes stellatus*	**17**								1		1	2	2	3	8														12	± 1.765	± 0.428
2	*Balistapus undulates*	**24**									1		1	2	2	3	2	6	3	1	2						1			15	± 3.31	± 0.67
3	*Canthidermis maculates*	**23**	12	1		1		2		3			1		2	1														3.6	± 4.630	± 2.151
4	*Melichthys indicus*	**22**										1	2	1		4	2	1	1	1		1			1			1	1	12	± 7.542	± 1.608
5	*Zenodon niger*	**93**											1	1	2	2	3	4	11	15	12	17	16	7	1	1				18	± 2.465	± 0.25
6	*Pseudobalistes viridescens*	**15**				1	1		1	3	1	2	1	2	1		2													8.8	± 3.277	± 0.846
7	*Pseudobalistes flavimarginatus*	**12**							1				3	2	3	3														11	± 1.975	± 0.570
8	*Rhinecanthus aculeatus*	**58**								1	3	10	30	11	2		1													10	± 1.076	± 0.141
9	*Sufflamen fraenatus*	**89**										2	1	1	5	14	13	19	11	9	5	4	4	1						15	± 2.426	± 0.257

Table 7 Number of anal rays

S. No.	Species	N	19	20	21	22	23	24	25	26	27	28	29	30	31	32	X	SD	SE
1	*Abalistes stellatus*	**17**						9	8								25.47	± 0.514	± 0.124
2	*Balistapus undulates*	**24**				1	17	6									23.2	± 0.508	± 0.103
3	*Canthidermis maculates*	**23**	1		6	8	8										21.95	± 1.012	± 1.010
4	*Melichthys indicus*	**22**									5	7	7	3			28.36	± 1.00	± 0.213
5	*Zenodon niger*	**93**									2	12	30	33	15	1	29.526	± 0.995	± 0.103
6	*Pseudobalistes viridescens*	**15**				2	6	6	1								23.4	± 0.828	± 0.213
7	*Pseudobalistes flavimarginatus*	**12**					2	8	2								24	± 0.603	± 0.174
8	*Rhinecanthus aculeatus*	**58**		1	18	34	4	1									21.7	± 0.683	± 0.089
9	*Sufflamen fraenatus*	**89**								3	42	38	3	3			27.56	± 0.768	± 0.081

Table 8 Number of scales from origin of second dorsal to base of anal

S. No.	Species	N	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	X	SD	SE
1	*Abalistes stellatus*	**17**						2	2	9	4											17	± 0.92	± 0.22
2	*Balistapus undulates*	**24**							1	3	8	8	3	1								19	± 1.14	± 0.23
3	*Canthidermis maculates*	**23**							1		3	12	4	3								19	± 1.11	± 1.05
4	*Melichthys indicus*	**22**										2	3	1	5	8	3					22	± 1.55	± 0.33
5	*Zenodon niger*	**93**	14	45	29	3	2															11	± 0.84	± 0.08
6	*Pseudobalistes viridescens*	**15**			3	9	3															13	± 0.65	± 0.169
7	*Pseudobalistes flavimarginatus*	**12**				3	7	2														14	± 0.66	± 0.19
8	*Rhinecanthus aculeatus*	**58**					13	16	20	9												15	± 1.01	± 0.13
9	*Sufflamen fraenatus*	**89**												2	8	16	38	17	4	3	1	24	± 1.27	± 0.13

S. No.	Species	N	20	23	24	25	26	27	28	29	30	31	32	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	54	55	56	57	58	59
1	*Abalistes stellatus*	**17**								1			1			1																				5	1	2	1
2	*Balistapus undulates*	**24**																		2			1	1	1	1		1	1		2	2	1	2	4	3	1	1
3	*Canthidermis maculates*	**23**																										1				1					1	
4	*Melichthys indicus*	**22**									1																										2	
5	*Zenodon niger*	**93**												1		1	2	2	3	5	4	6	4	11	13	9	7	11	7	5	1	1						
6	*Pseudobalistes viridescens*	**15**																1	1	2	1		1	2	2	2	3											
7	*Pseudobalistes flavimarginatus*	**12**																		1			4	2	3	1	1											
8	*Rhinecanthus aculeatus*	**58**	1	1	2	4	5	1	2	2		1	3	5	1	2			3	4	1	4		3	3	3	2	2		2	1							
9	*Sufflamen fraenatus*	**89**																																	1			

S. No.	Species	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	83	X	SD	SE
1	*Abalistes stellatus*	1	1		2					1														54.35	± 11.067	± 2.684
2	*Balistapus undulates*																							51.54	± 5.8	± 1.19
3	*Canthidermis maculates*		1	4	3	3	1	4	1	1	1	1												63.08	± 4.99	± 2.23
4	*Melichthys indicus*	1			1	1	1	2		2	3			2	2	1	1		1	1				66.6	± 9.9	± 2.12
5	*Odonus niger*																							44.74	± 3.69	± 0.383
6	*Pseudobalistes viridescens*																							43.46	± 3.113	± 0.803
7	*Pseudobalistes flavimarginatus*																							44	± 1.809	± 0.522
8	*Rhinecanthus aculeatus*																							36.17	± 8.622	± 1.132
9	*Sufflamen fraenatus*	1		1	3		1	4	2	5	9	6	2	11	7	6	9	8	5	1	3	3	1	72.01	± 4.789	± 0.507

Table 10 Number of scales round the caudal peduncle

S. No.	Species	N	7	8	9	10	11	12	13	14	15	16	17	18	X	SD	SE
1	*Abalistes stellatus*	**17**			3	11	1	2							10.11	± 0.85	± 0.20
2	*Balistapus undulates*	**24**	1		16	6	1								9.25	± 0.73	± 0.15
3	*Canthidermis maculates*	**23**					1	2	8	9	3				13.47	± 0.99	± 0.99
4	*Melichthys indicus*	**22**						3	5	3	4	4		3	14.5	± 1.91	± 0.40
5	*Odonus niger*	**93**			31	54	7	1							9.76	± 0.63	± 0.065
6	*Pseudobalistes viridescens*	**15**				14	1								10.06	± 0.25	± 0.169
7	*Pseudobalistes flavimarginatus*	**12**				9	3								10.25	± 0.45	± 0.13
8	*Rhinecanthus aculeatus*	**58**			44	9	3	2							9.36	± 0.74	± 0.09
9	*Sufflamen fraenatus*	**89**							5	41	32	10	1		14.5	± 0.81	± 0.085

2.5.10. Key to the Genera of the Family Balistidae of India

Body, oval to rhomboid, covered with strong diamond shaped scale. Each scale has vertical rows of protuberances. A groove present before eye and below nasal. First dorsal fin with three spines, first spine stout and can be locked upright by the second spine thus forming a trigger mechanism. The third spine, small and insignificant. Second dorsal fin and anal fin are similar with a single simple ray and many branched rays. Pectoral with one simple ray and 12 – 14 branched rays. Caudal has 10-branched rays and two simple rays one above and below. Enlarged scales present above pectoral base. Scales on cheek are of many types rhomboid or square or rectangular or triangular, which occur in combinations. In some, the cheek is anteriorly without scales and posteriorly cheek with few rows of scales . Scales on abdomen rectangular to rhomboid. Caudal peduncle has few to many rows of ridges or antrose spines or spherical protuberances. Pelvic fin reduced to a spine.

2.5.10.1. Key to Genera of family Balistidae

- Groove present ---------- 1

- Groove absent ---------- 2

1 Caudal peduncle longer than deep, dorsoventrally flattened, with 3-4 rows of ridges, ----------*Abalistes*

1a Caudal peduncle twice as deep as long, cylindrical,, with 3-4 rows of narrow broken ridges, ----------*Melichthys*

1b Caudal peduncle, cylindrical, equally long and deep, with 2-8 rows of glassy Spherical blunt protuberances, scales on cheek rhomboidal, obliquely arranged, two upper lateral red tooth, produced and canine like----------*Zenodon*

1c Caudal peduncle, cylindrical, equally long and deep, without protuberances, scales on cheek rectangular and rhomboidal, obliquely arranged, Second dorsal and anal

elevated and some times filamentous, caudal rounded with upper and lower lobes produced----------*Balistes*

1d Caudal peduncle deeper than long----------3

2a Caudal peduncle laterally flat, deeper than long, with 2-3 rows of black, large antrose spine, scales on cheek rectangular and hexagonal, vertically arranged -----
----------*Balistapus*

2b Caudal peduncle cylindrical, equally long and deep, with 3-4 rows of black, antrose spines ---------- 4

3a Caudal peduncle cylindrical ---------- 5

3b Caudal peduncle laterally flat ---------- 6

4a Scales on cheek, square, triangular and rectangular, horizontally arranged ----------
---------- *Rhinecanthus*

5a Caudal peduncle with 5-10 rows of spherical blunt glassy protuberances or 2-4 rows of glassy antrose spines, scales on cheek, rectangular or square, triangular and rectangular ---------- ----------*Sufflamen*

5b Caudal peduncle with 3-6 rows of spherical blunt protuberance with one or two protuberances pointed, scales on cheek, diamond shaped, vertically arranged or square and rectangular, horizontally arranged with wide fleshy grooves, cheek without scales around mouth---------- *Pseudobalistes*

5c Caudal peduncle with 4 - 8 rows of ridges , scales on cheek rectangular, arranged in horizontal rows, in some oblique rows, with narrow fleshy grooves----------
----------*Xanthichthys*

5d Caudal peduncle without protuberances, scales on cheek present, two cylindrical bulging laterally below pectoral ----------*Xenobalistes*

6a Caudal peduncle with 3-9 rows of ridges, scales on cheek rhomboid, horizontally arranged, fleshy areas grooves in-between scale rows, ear ossicles absent----------
----------*Canthidermis*

6a Caudal peduncle with 3-9 rows of diamond shaped scales, each scale have anterior row of ridges, scales on cheek Square, horizontally arranged, wide fleshy rows in between----------*Parabalistes*

2.5.10.2. Key to the species of fishes of the family Balistidae of India based on the scales

Fishes of this family was earlier identified based on the colour pattern possessed by these fishes, on the shape of the fishes, fin shape and ray counts, and based on the presence or absence of scales on the cheek. A new type of key was developed to identify these fishes based on the scale pattern and type of protuberances it possessed.

- Scales on cheek rhomboid, arranged in vertical rows, anteriorly and in oblique rows posteriorly ---------- 1.
- Scales on cheek rhomboid and square, arranged in transverse rows---------- 2.
- Scales on cheek square and rhomboid, arranged in transverse rows with wide transverse fleshy row in between---------- 3.

1a. Rhomboid scales on cheek have lateral ridges arranged in 3-5 rows vertically - ---------- *Melichthys indicus.*

1b. Rhomboid scales on cheek have ridges as the first row followed by round protuberances arranged in 5-8 vertical rows ---------- *Zenodon niger*

1c. Rhomboid scales on cheek have round protuberances ---------- 4.

2a. The scales are square at the anterior and rhomboid and rectangular posteriorly ---------- *Canthidermis maculates*

2b. The scales are completely rectangular---------- *Sufflamen fraenatus*

2c. The scales are square at the anterior, with rhomboid scale at the posterior with some triangular scale in between ---------- 5.

3a. Cheek is scaled anteriorly with irregular shaped scales, posteriorly with rhomboid scales with fleshy rows in between---- *Pseudobalistes viridescens.*

3b. Scales are absent anteriorly and at the posterior 3-5 transverse ridges are present, having square to rectangular scale, between the ridges are present wide fleshy rows in between (The fleshy interscale also has rectangular elongated scales which is completely covered by epidermis)---------- ---------- *Pseudobalistes flavimarginatus.*

3c. The scales are absent anteriorly, posteriorly transverse rows of square scales are present with wide fleshy row in between (The fleshy interscale also has rectangular elongated scales which is completely covered by skin) ---------- ---------- *Parabalistes fuscus.*

4a. Body scales have a spherical protuberance at the anterior middle and ridges as the first row followed by round protuberances arranged in 5-8 vertical rows Scales on caudal peduncle have a transverse ridges at the centre and 3 -5 horizontal rows of round protuberance ---------- *Abalistes stellatus.*

4b. Body scale with 2 - 4 vertical rows of retrose spines. Caudal peduncle has two types of scales 1) Diamond shaped scales with central antrose spine and 5-8 horizontal rows of ridges. 2) Diamond shaped scales with ridges and retrose spines arranged in 2 –4 vertical rows. ---------- *Balistapus undulatus.*

4c. Body scales with a spherical pointed protuberance at the anterior middle and 4-6 vertical rows of round protuberances. Scales on caudal peduncle are of two types i) scales with a large spherical protuberance at the anterior middle of the scale and round protuberances, ii) scales with round protuberances arranged in vertical rows ---------- *Pseudobalistes conspicillum.*

5a. The body scales have 3 - 4 vertical rows of ridges and blunt retrose spines. The caudal peduncle has 3-4 rows of antrose spines. Scales on caudal peduncle are of two types 1) scales having 3-5 rows of antrose spines and also an antrose spine at the centre. 2) Scales having 3-5 vertical rows of blunt retrose spines ---------- *Rhinecanthus aculeatus.*

5b. Body scale has 5-6 horizontal rows of blunt retrose spines the caudal peduncle has 2 rows of antrose spines. Scales on caudal peduncle are of two types 1) wedge shaped scales with an antrose spine at the middle and 1-2 rows of ridges, 2) diamond shaped scales having 4-5 vertical rows of ridges ----------
---------- *Rhinecanthus echarpe.*

5c. Body scales have blunt retrose spines arranged in 3-6 vertical rows. The scales at the caudal peduncle has 5-8 rows of antrose spines, scales on caudal peduncle are of two types i) scales with an antrose spine at the anterior middle and 3-5 vertical rows of blunt retrose spines and ridges. ii) Scales have blunt retrose spines and ridges arranged in 3-6 vertical rows. ----------
----------*Sufflamen chrysopterus.*

Chapter 3

Biology

3. BIOLOGY

3.1. Introduction

The trigger fishes are specialized teleosts of the tropical, subtropical, Atlantic and Indo-pacific oceans. In India there are 9 genera comprising of 13 species. The available records show that these fishes form an important component of the marine fish landings at Kanyakumari, Colachel, Tuticorin and Veraval. A major portion of the catch is sun dried and converted into fishmeal, which is used for the production of poultry feed. A small quantity of the fresh catch is exported. Few species are beautiful marine aquarium fishes and have a good share in the ornamental fish trade.

A perusal of the literature on these fishes shows that there is no adequate information on biology from any single region.

Menezes (1985) studied the reproductive biology and growth of *Balistes vetula* of Brazilian waters. Gladstone (1994) made a study on the reproductive behavior of Balistids of Australian waters. Ishihara and Kuwamura (1996) made observation on the reproductive behavior and mating systems of *Sufflamen chrysopterus* of Sesoko Islands in Okinawa at Japan. Kuwamura (1997) studied the parental care of eggs in haremic *Rhinecanthus aculeatus*.

Macedo Costa *et. al.*, (1987) made a study on the food and feeding habits of *Balistes vetula* of Brazil. Other workers have studied its food and feeding from different regions of the world: Abitia *et. al.*, (1990) on *Balistes polylepis* of Gulf of California. Robert *et al.* (1990) on the predatory behavior of *Balistes capriscus* on Japanese clam, Vose and Nelson (1991) on feeding of *Balistes capriscus* living in artificial and natural substrate in shallow Atlantic waters off Florida. Kurz (1994) made a study on predator-prey interactions between the gray trigger fish (*Balistes capriscus*) and a guild of sand dollars around artificial reefs in the northeastern Gulf of Mexico.

Danson (1989) estimated growth in *Balistes capriscus*, based on growth rings in the first dorsal spine. Domanevski and Sazonov (1993) studied the population dynamics of the eastern Atlantic trigger fish *Balistes carolinensis.*

Essuman (1989) made a survey on the production and utilization of trigger fish at Ghana. Radolato *et. al.,* (1994) is of the opinion that lipids like eicosapentaenoic (C20:5) and docosahexaenoic (C 22:6) which are used for prevention and treatment of certain cardiovascular diseases are present in higher quantities in the fillets of *Balistes carolinensis*.

Robertson (1988) recorded the variation in settlement of the Caribbean trigger fish *Balistes vetula* at Panama. Kuwamura (1991) studied habitat partitioning among 10 species of Balistids fishes on the coral reef of Sesoko Islands in Okinawa at Japan. Lindberg and Frazer (1994) made a study on the reef unit spacing, population structure and habitat linkages of *Balistes capriscus*.

Karyotype and banding analyses in trigger fish was made by Takai and Ojima (1988). Energetic of swimming in trigger fish was studied by Korsmeyer *et.al.,* (1999). Feeding and territorial behavior in juveniles of some co-existing trigger fishes was recorded by Chen *et al.* (2001).

In view of the limited information on the biology of balistids from any part of the world and from India in particular, investigations on some aspects of its biology were initiated in April 1999 and continued up to May 2000 on *Zenodon niger* and *Sufflamen fraenatus*. The results of these investigations are presented here.

3.2. Material and methods

The material for this study was collected from Kanyakumari and Tuticorin every month, for periods ranging from 3 to 5 days. Total length, standard length and weight of each specimen were measured in the field in fresh condition. Gonads were also examined

in fresh condition for colour, state of maturity and relative size, and these were preserved in 5% formalin. Microscopic examination of ovaries was made in preserved specimens. The details of material examined and methods adopted are given at the beginning of relevant chapters.

3.3 Length – Weight Relationship

The determination of the relationship, between the length and the weight of the fishes has been recognised as important in fishery biological studies. The study of length-weight relationship of fishes has three major purposes. First it establishes the mathematical relationship between the two variables, length and weight, so that the unknown variable can be readily calculated from the known variable. Secondly, the relative condition to assess the general well being, gonad development and indication of fat can be estimated. The value of regression coefficient is a parameter of the yield equation of Beverton and Holt (1957). David (1963) reported that there were also possibilities of the length weight relationship turning out to be useful tools in the recognition of different stocks of the same species. According to Le Cren (1951) the length-weight relationship is useful to distinguish small taxonomic units.

Length-weight relationship is determined by collecting data on both the length and the weight of the fish in different phases of life and calculating the relationship existing between the two by the formula $W = a L^{b}$

W is the weight of the fish,
L is the length of the fish and
a and b are constants to be determined empirically from the data.

The importance of length-weight relationship of fishes has led a large number of workers in different parts of the world to analysis this relationship in both freshwater and marine fishes. This relationship may vary in diverse stocks and sexes of the same stock. It has also been shown that a single equation may not necessarily describe the relationship for the entire length range. Some works have derived the equation without separating the two sexes, most others have determined the relationships for the males and females separately, and sometimes also for the juveniles and even different size- group.

In fishes, generally the growth pattern follows the cube law (Lagler, 1952). Such cubic relationship for fishes will be valid when the fish grows isometrically. But in

reality, the actual relationship between the variables length and weight may depart from this, either due to environmental conditions or condition of fish (Le Cren, 1951). In the majority of fishes the shape and density change with increasing age, which often causes the regression coefficient of weight on of length, depart from 3. In such cases the value of the exponent 'b' in the parabolic equation may lie between 2.5 and 4 (Hile, 1936; Martin, 1949).

The length weight relationship of a few species in the fishes of the family Balistidae have been studied. Aiken (1975) studied the length weight relationship of *Balistes vetula* and *Canthidermis sufflamen* from the Caribbean. Balasubramanian *et. al.* (1995) made a study of this relationship on *Sufflemen fraenatus*, *Odonus niger* and *Balistes niger* from the trawl landings at the Tuticorin fisheries harbour. Gracia *et. al.* (1998) have determined the length-weight relationship of *Balistes vetula* from the Gulf of Salamanaca, Columbia. This relationship was determined for *Abalistes stellatus* and *Sufflamen fraenatus* from the coral reefs and lagoons of New Caledonia, by Letourneur *et. al.* (1998).

The determination of the exact nature of the relationship that exists between the length and weight of fishes has been recognised as an important part of fishery biological studies. In view of this practical utility, an attempt was made to determine the length-weight relationship of *Sufflamen fraenatus* and *Zenodon niger* from the Indian seas.

3.3.1. Material and methods

The length-weight relationship of *Sufflamen fraenatus was* estimated with the sample collected from the hook and line landings centre at Tuticorin. In *Zenodon niger* also this relations ship was established from the samples collected from the trawl landing at Kanyakumari. The length weight relationship of *Sufflamen fraenatus* is based on 516 specimens of which 237 females ranging from 175 – 311 mm (TL) and 279 males ranging from 169 - 358 mm (TL), collected during the period April 1999 to April 2000 from Tuticorin. In *Zenodon niger* the study is based on 227 specimens, of which 130 females ranging from 158 – 277 mm (TL) and 97 males ranging from 169 – 282 mm

(TL) collected during the period June 1999 to April 2000. After being measured for total length (mm) and weight (to nearest gram), the specimens were cut open to note the sex. The weight was measured in fresh condition.

The method suggested by Le Cren (1951) was followed to compute the length and weight relationship. According to this the length-weight relationship can be expressed as:

$$W = a L^{b}$$

Where W and L are weight and length of the fish respectively and 'a' and 'b' are two constants (i.e. initial growth index and regression constants respectively).

When expressed logarithmically the above equation becomes a straight line of the formula:

$$\text{Log } W = \log a + b \log L,$$

The constants a and b were estimated by the method of least square (Snedecor and Cochran, 1967). The regression of log weight on log length was first calculated separately for males and females and then for the species.

Analysis of covariance (Snedecor and Cochran, 1967) was employed to find out whether the regression coefficients differed significantly between males and females. The significance of difference, in the estimate of 'b' in males, females and pooled data of sexes from the expected value of 3 (isometric growth) was tested by the 't' test as given by the formula,

$$t = \frac{b - 3}{S_b}$$

b = regression coefficient of log transformed data.

Where,

$$S_b = \frac{\sqrt{1/n-2\ \Sigma y^2 - (\Sigma x)^2}}{\sqrt{\Sigma x^2}}$$

x,y and xy corrected terms, n-2 degree of freedom.

3.3.2. Results

Sufflamen fraenatus

A total of 514 specimens of *Sufflamen fraenatus*, 278 males length ranging from 169-358mm; 236 females length ranging from 175-311mm were used for the study.

The results of regression analysis in the two sexes are presented in the table 11. Analysis of co variance (Table12) showed that the difference between the regression coefficient of the two sexes was not significant, hence the data were pooled and equation obtained is:

$$\text{Log } W = -9.0429 + 2.7296 \log L$$

$$\text{or } W = 0.000000000905 * L^{2.72776}$$

$$R^2 = 0.9301$$

The scatter diagrams of length-weight relationship are presented in the figures 84 A&B.

Table 11. Sum of squares and products of length-weight data of *Sufflamen fraenatus*

Sex	$\overline{X}$	$\overline{Y}$	n	Sum of squares and product			a	b	Errors of estimate	
				S_{x2}	S_{xy}	S_{y2}			df	ss
Males	5.658	6.391	278	3.225	9.169	29.446	-9.753	2.853	277	3.179
Females	5.480	5.929	236	2.410	6.697	20.926	-9.357	2.789	235	2.155
Pooled	5.575	6.177	514	9.704	26.420	77.69	-9.043	2.729	513	5.469

$\overline{X}$ = Mean logarithmic length

$\overline{Y}$ = Mean logarithmic weight

a = Y- intercept

b = regression coefficient

S_{X2}, S_{Y2} = corrected sum of squares of length and weight respectively

S_{XY} = corrected sum of products of length and weight

df = Degree of freedom

ss = Sum of squares

Table 12. Analysis of covariance of *Sufflamen fraenatus*

Source of variation	df	ss	MSS
Deviation from individual regression within sexes	513	5.469	0.0106
Difference between regression	1	0.006	0.00557
Deviation from total regression	514	5.469	0.01064

F = 0.53, df = 1, 514, F at 5% = 3.84, Not significant.

Zenodon niger

A total number of 227 specimens of *Zenodon niger* were used for the study, (97 males of length ranging from 169 to 282 mm; 130 females of length ranging from 158 to277 mm) collected during the period June 1999 to April 2000. The fishes were collected from the trawl catches at Kanyakumari landing centre.

The results of regression analysis of log weight on log length in the two sexes are presented in the table 13. Analysis of covariance (Table14) showed that the difference between the regression coefficients of the two sexes is not significant, hence the data were pooled and relationship calculated for the species:

$$\text{Log } W = -6.507 + 2.085 \log L$$

$$\text{or} \quad W = 0000003117 * L^{2.08556}$$

$$R^2 = 0.6749$$

The scatter diagrams of length and weight relationship are presented in the figures 85 A&B.

Table 13. Sum of squares and products of length weight data of *Zenodon niger*

Sex	$\overline{X}$	$\overline{Y}$	n	Sum of squares and product			a	b	Errors of estimate	
				S_{X2}	S_{XY}	S_{Y2}			df	ss
Males	5.459	4.840	97	1.600	3.463	13.791	-7.098	2.186	96	6.075
Females	5.325	4.628	128	1.085	2.584	7.472	-8.152	2.399	127	1.212
Pooled	5.383	4.719	226	3.673	7.627	23.673	-6.507	2.085	225	7.660

$\overline{X}$ = Mean logarithmic length

$\overline{Y}$ = Mean logarithmic weight

a = Y- intercept

b = regression coefficient

S_{X2}, S_{Y2} = corrected sum of squares of length and weight respectively

S_{XY} = corrected sum of products of length and weight

df = Degree of freedom

ss = Sum of squares

Table 14 Analysis of covariance of *Zenodon niger*

Source of variation	df	ss	MSS
Deviation from individual regression within sexes	225	7.660	0.0340
Difference between regression	1	0.027	0.02677
Deviation from total regression	226	7.661	0.03405

F = 0.82, df = 1, 225, F at 5% = 3.84, Not significant.

3.3.3. Discussion

The 'r' values showed a very good correlation between length and weight in the case of *Sufflamen fraenatus*. The analysis of variance of regression co-efficients was insignificant in both the species. The length-weight relationship of *Sufflamen fraenatus* and *Zenodon niger* obtained by different workers varied.

The length weight relationship of *Sufflamen fraenatus* obtained by Balasubramanian *et. al.*, (1995) form the fish landings at Tuticorin fisheries harbour had 'b' value of 2.4357 (TL min. = 140 mm, TL max. = 214 mm) for *Zenodon niger* 'b' value of 2.7376 (TL min = 120 mm, TL max = 184 mm.). Letourneur *et. al.* (1998) obtained 'b' value of 2.950 (TL min. = 19 cm, TL max. = 36.4 cm) for *Sufflamen fraenatus* and 'b' value of 2.692 (TL min. = 14 cm, max. = 53.5 cm) for *Abalistes*

stellatus from New Caledonia. Here the 'b' value for *Sufflamen fraenatus* is close to 3 (i.e. the growth is isometric). However, the above values were not subjected to any statistical testing and hence the comparison with the present investigation is not possible.

In *Sufflamen fraenatus* there is not much difference between the 'b' values among the males and females were as in case of *Zenodon niger* the 'b' values have marginal variations, because the males are longer than females. In both the cases the 'b' value is lower than the isometric value 3. The value of the exponent 'b' in the parabolic equation usually lies between 2.5 and 4 (Hile, 1936; Martin, 1946). Beverton and Holt (1957) stated that major deviations from isometric growth are rare.

Depending upon the deviation of 'b' values from '3' fishes can be classified into three groups (i) $b = 3$ where the body form of fish remains constant at different lengths (isometric) (Allen, 1938), (ii) $b < 3$ when fish becomes more slender as the length increases and (iii) $b > 3$ (allometric) when fish grows more stouter with increase of length (Growner and Juliano, 1976). The present observation is also in agreement with the above view and it can be concluded that the cube formula $W = a l^3$ will not be a proper representation of the length-weight relationship for *Sufflamen fraenatus* and *Zenodon niger*

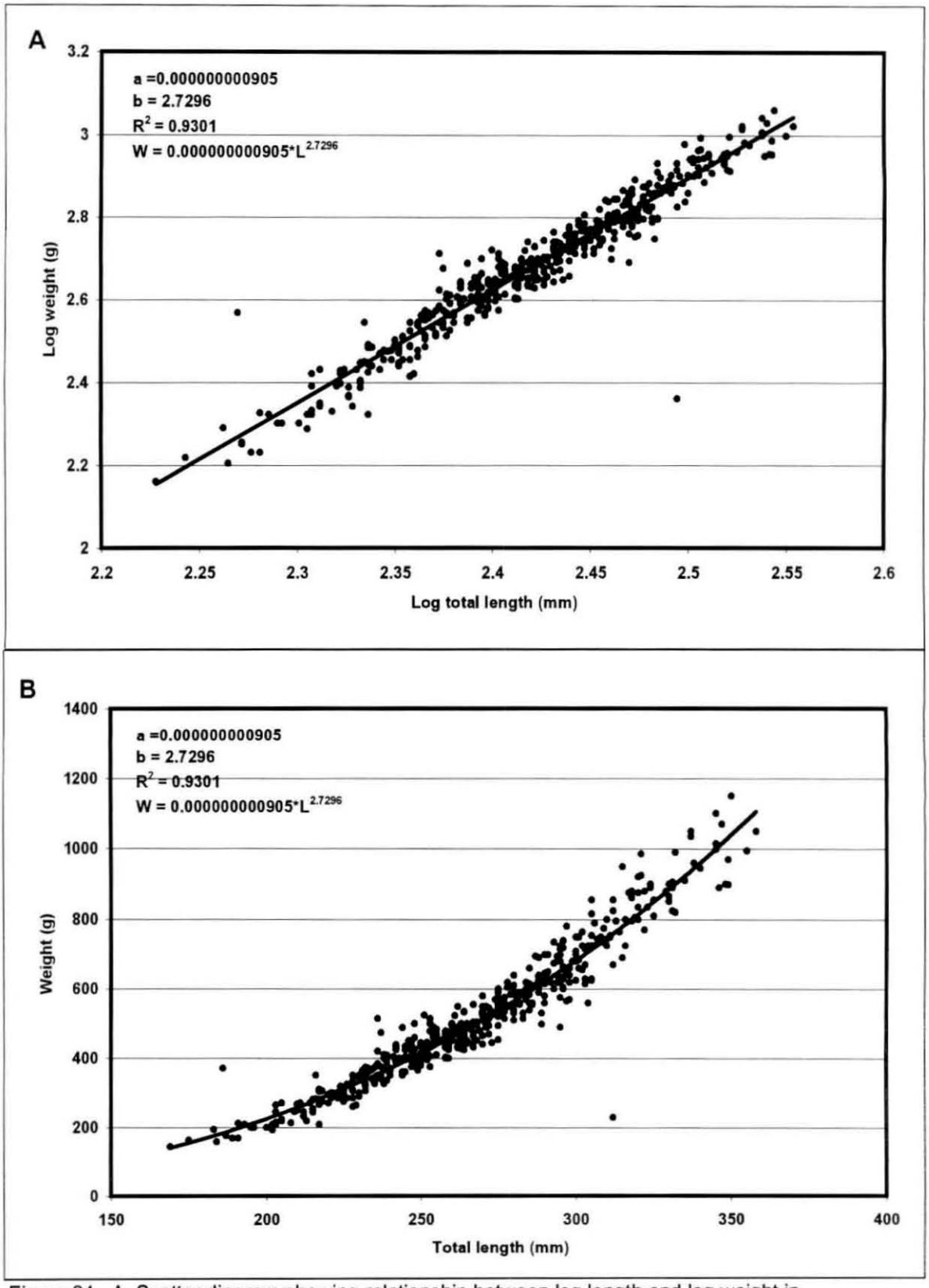


Figure 84 A. Scatter diagram showing relationship between log length and log weight in *Sufflamen fraenatus*

B. Regression of length-weight relationship in *Sufflamen fraenatus*

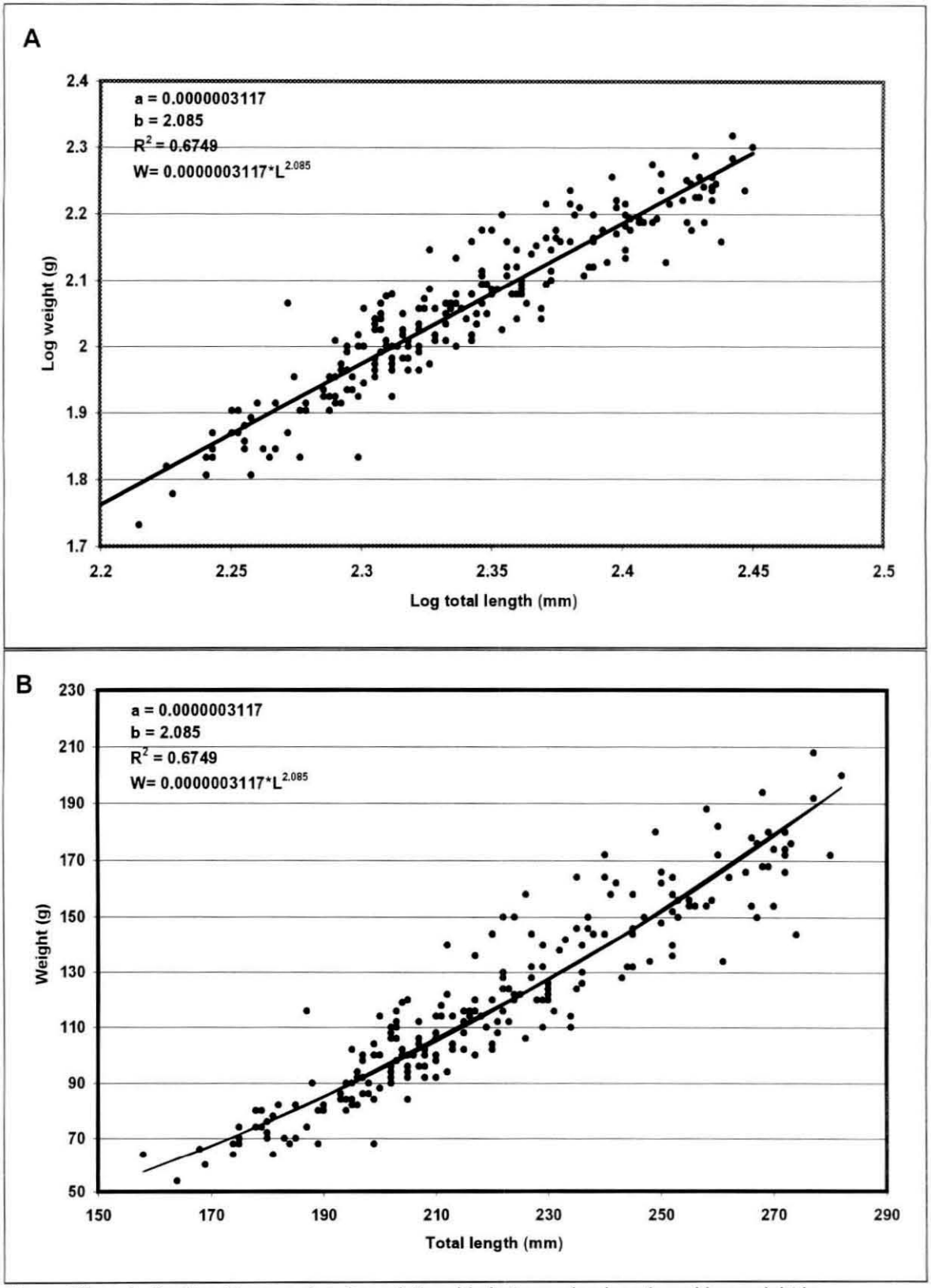


Figure 85 A. Scatter diagram showing relationship between log length and log weight in *Zenodon niger*
B. Regression of length-weight relationship in *Zenodon niger*

3.4. MATURATION, SPAWNING AND FECUNDITY

3.4.1. Introduction

A study of the cyclical changes in the gonads is aimed at understanding and predicting the changes, which the population undergoes annually, through reproduction and the resultant regeneration of stocks. This also helps in the conservation and management of resources. Some of the other aspects like fecundity estimates help in understanding reproductive potential of the stock; size and age at first maturity, is useful in assessing the potential stock recruited to the population; while sex ratio study, helps in understanding whether any preferential fishing exists, its possible bearing on the fishery and whether sexual congregation takes place during spawning. All the above said studies help in elucidating both short-term and long-term variation in fish, which are finally recruited in to the population as exploitable stocks.

Several studies have been conducted on maturation and spawning of trigger fishes from around the world. Nzioka (1979) studied the spawning period of *Abalistes stellaris* from the East African reef. According to Lobel and Johannes (1980) *Pseudobalistes flavimarginatus* and *Balistapus undulatus* of western Carolina Islands have a prolonged spawning period. Fricke (1980) recorded spawning behaviour of *Pseudobalistes fuscus* and *Odonus niger* in the Red sea. Aiken (1983) made a study on *Balistes vetula, Canthidermis sufflamen, Melichthys niger* and *Xanthichthys ringens* of the Caribbean. Menezes (1985) studied the sex ratio of *Balistes vetula* (Linnaeus) of Brazil. Danson (1990) gathered information on the spawning period of trigger fishes (*Balistes capriscus)* from the coast of Ghana. Gladstone (1994) made a preliminary study on the spawning behaviour of *Pseudobalistes flavimarginatus*, *P. fuscus*, and *Balistoides viridescens* of the Great Barrier Reef Marine Park. Kuwamura (1997) made an under water study of the spawning behaviour in *Rhinecanthus aculeatus* of the Sesoko Island, Okinawa. However, there is no information on maturation and spawning in Indian balistids.

The present study was hence undertaken to obtain this information on *Sufflamen fraenatus* and *Zenodon niger* from the east coast of India in general and Tamil Nadu coast in particular.

3.4.2. Material and methods

The study is based on 528 specimens of *S. fraenatus* comprising 289 males and 252 females of the size ranging from 175 to 358 mm TL collected from commercial catches obtained through hooks and lines from the landing centre at Tuticorin. In the case of *Z. niger* the study is based on 634 specimens, comprising 97 males, 131 females and 406 immature specimens in the size ranging from 82 – 282 mm TL and collected from the trawl catches from a landing centre at Kanyakumari.

After measuring length and weight of each specimen, the belly was cut open to note the sex, colour and general appearance of the gonads, the gonads were then carefully removed and preserved in 5% formalin, in labelled bottles. Detailed, careful observations were made on the maturation of the gonads, both ovaries and testis. Gonad tissues were teased out and examined under high power microscope.

a) Classification of ovaries into different stages of maturation

Maturation refers to the cyclic morphological and cytological changes that the male and female gonads undergo to attain full growth and ripeness (Qasim, 1973). To distinguish these changes, it is necessary to understand the regular and periodic transformations taking place in the gonad. These variations are to be recognised and graded into a set of distinctive stages that best describes the state of maturity of the gonads, as it pass through the different stages before the fish spawns.

The quantification of these stages of maturity was made based on the colour, shape, size and girth of the ovary and the microscopic study of the ova. There are a large number of classifications for describing the stages of maturity, put forward by different workers. But in the present study four stages (immature, maturing, mature and ripe) of maturation was recognised based on the colour, shape and size of the ovary in relation to the body cavity and microscopic study of the ova. The method described by Prabhu (1956) and Qasim (1973) was followed in the present work. The

cycle of maturation of gonads were studied in detail in the balistids selected by first defining the stages of sexual maturity which was followed at monthly intervals in samples fairly representative of the population.

b) Ova diameter frequency distribution

For the study of ova diameters, transverse sections of ovary (about ¼ cm thick) from the anterior, middle and posterior regions were taken; the ova were teased out on micro slides, taking utmost care to separate out all the ova in the samples. The ova were measured under a microscope with the help of an ocular micrometer at a set magnification (each micrometer division (m.d.) is equal to 0.011 mm). In maturing and mature ovaries; around 600 ova from each ovary were measured; in immature ovaries, since there was not much variation in the diameters of different ova, about 200 ova from the middle region were measured. This method has been successfully employed by Clark (1934), De Jong (1940), June (1953), Yuen (1955) and by several Indian workers, Palekar and Karandikar (1952, 1953), Prabhu (1956), Dharmamba (1959), Rao (1964), Raja (1967), Rao (1967) and Luther (1963) . Measurement of ova diameters in different stages of maturity was taken from 30 ovaries of *S. fraenatus* ranging from 175-358 mm TL and 15 ovaries of *Z. niger* ranging from 140 – 282 mm TL for this study. Frequency distribution of ova of different sizes (1- 42 m.d.) was divided into diameter groups of two-micrometer divisions each (i.e. 2-3, 4-5, 6-7 and so on up to 41-42 m.d.). The percentage frequency distribution of ova in ovaries of different stages of maturity is presented in the figures 86 & 87.

c) Determination of length at first maturity

For determining the length at first maturity, specimens with ovaries in mature condition were considered; the proportion of such mature fish in each length group was also determined. The length at which about 50% of the fishes were mature, was taken as the length at first maturity. As almost all the adult fish during the spawning season (or at least peak spawning season) are expected to be in mature stage, it is desirable to consider representative samples collected during this period for this purpose to eliminate the possibility of growth in length influencing the estimate of the length at first maturity.

d) Spawning period

The periodicity of spawning has been determined using the ova diameter frequency distribution in mature ovaries following Hickling and Rutenberg (1936) and De Jong (1940).

First of all the distribution of sexes and maturation stages in fishes of different length groups in *S. fraenatus* and *Z. niger* were recorded. The spawning period was determined using the data on maturation stages in different months and the months of occurrence of gravid fishes. For this purpose only fishes above the length at first maturity were considered as this would help in determining the peak spawning period more satisfactorily. Applying the method of June (1953) and Yuen (1955) the relative weight or the gonado-somatic index was calculated by using the formula:

$$\text{Gonado-somatic index (GSI)} = \frac{\text{Weight of gonad (g)}}{\text{Weight of fish (g)}} \times 100$$

The monthly mean index values were calculated separately for males and females, to determine the spawning period.

The relative condition (Kn) was calculated using Le Cren's (1951) formula

$$\text{Relative condition factor (Kn)} = \frac{\text{Observed weight of fish (W)}}{\text{Calculated weight derived from the length-weight relationship } \hat{W}}$$

This value is calculated to investigate 'condition', 'fatness' or general 'well-being'. The mean Kn values for both sexes were computed separately for various months, to know the spawning period.

e) Fecundity

Estimation of fecundity is based on the number of mature ova present in the ovaries. According to Bagenal (1968) all the ova destined to spawn during the ensuing

season are mature in ovaries in the penultimate stage of ripeness. The mature ovaries collected during the study period, were weighed in electronic balance to the nearest milligram (after removal of excess formalin by absorbing in filter paper); a small piece cut from the middle of the right ovary was weighed and transferred to a small bottle containing 5% formalin; the bottle was shaken to free the ova from the ovarian tissue; ova still attached to the ovarian tissue were released on a slide and separated with fine needles. After separating all the ova from the ovarian tissue they were transferred to Sedgewick - Rafter Counting Cell and all the larger, opaque ova above 20 md (0.22 mm) were counted under microscope. From this the fecundity was estimated by adopting Holden and Raitt's (1974) formula,

$$\text{Fecundity (F)} = \frac{\text{Number of eggs in the sub sample (n) x Total weight of the ovary (g)}}{\text{Weight of sub sample in the same unit (g)}}$$

The relationship between fecundity and different variables like fish length, fish weight and ovary weight was worked out by the least square method $F = a X^{b}$ where F= fecundity, x = fish length or fish weight or ovary weight, a = constant and b = regression co-efficient. The exponential relationship was transformed into a straight-line relationship based on logarithms to the following equation,

$$\log \text{fecundity} = \log a + b * \log x.$$

3.4.3. Results

a) Morphology of the reproductive organs

The ovaries of *Sufflamen fraenatus* are short, cylindrical and sac like lying posterior to body cavity. Both the lobes are of equal size with a narrow oviduct ventrally. The whole ovary is pink in colour when immature, but turn yellowish when mature. A small yellow globular tissue is found on the paired ovary wall, where the oviduct meets the ovary.

The ovaries of *Zenodon niger* are also short, cylindrical and sac like lying posterior to body cavity. Both the lobes are of equal size with a narrow oviduct ventrally. The whole ovary is pink in colour when immature, maturing ovaries are of slightly larger size.

The ovaries of these two species in various stages of maturity show a gradation, which is found to be characteristic of the species. A scale of only four stages of maturity is found practicable for these species as against the 7 stages followed by I.C.E.S. Prabhu (1956) followed the four stages and Qasim (1973) also suggested four stages.

The maturity stages observed in the present study are given below in table 15 & 16.

Table 15. Maturity stages observed in ***Sufflamen fraenatus***

Stage	**Ovary**
Immature	Ovary small, pink in colour, round, with four globular structures. Ova transparent without yolk, diameter ranging from 2 to 8 m.d. (0.022 - 0.088 mm).
Maturing	Ovary cylindrical, pink in colour. Ova shape irregular or spherical, yolk deposition initiated, yellowish-brown, translucent, nucleus barely visible, ova diameter ranging from 2-16 m.d. (0.022 - 0.17 mm).
Mature	Ovary cylindrical, yellow in colour, occupy ¼ the body cavity Mature ova - shape spherical, opaque, diameter ranging from 2 - 42 m.d. (0.022 - 0.462 mm).
Ripe	This stage was not encountered during study period

Table 16. Maturity stages observed in ***Zenodon niger***

Stage	Ovary
Immature	Ovary small, cylindrical, pink in colour, round, with four globular structures. Ova spherical or irregular shaped with a central nucleus, ova diameter ranging from 1 to 7 m.d. (0.011-0.077 mm)
Maturing	Ovary larger than immature ovary, cylindrical, pink in colour. Ova shape irregular or spherical, yolk deposition initiated, yellowish-brown, translucent, nucleus barely visible, ova diameter ranging from 2 to 20 m.d. (0.022-0.22 mm).
Mature	This stage was not encountered during study period
Ripe	This stage was not encountered during study period

1) Stages of maturity

a) Ovary in *Sufflamen fraenatus* and *Zenodon niger*

Four distinctive maturity stages in ovary were identified,

i) Immature

Ovary small, pink in colour, round, with four round lobes in case of *Sufflamen fraenatus*. Ova diameter ranging from 2 to 8 m.d. (0.022-0.088 mm) (Fig. 86. B & Fig. 87. A, B.).

In *Z. niger* the ovary is cylindrical and small. Ova diameter ranging from 1 to 7 m.d. (0.011-0.077 mm) (Fig. 86. D).

Ova, shape irregular, translucent, yolkless and nucleus clearly visible.

ii) Maturing

Ovary cylindrical, pink in colour, two small round structures are present on the ovary between the ovary the oviduct. Ova diameter ranging from 2-16 m.d. (0.022-0.17 mm) (Fig. 87. C, D.).

In *Z. niger* the ovary is cylindrical and slightly larger than the immature ovary. Ova diameter ranging from 2 to 20 m.d (0.022-0.22 mm).

Ova shape irregular rarely spherical, yolk deposition initiated – with globular yolk, yellowish-brown, translucent, nucleus barely visible.

iii) Mature

Ovary cylindrical, yellow in colour, occupy ¼ the body cavity, the two round structures diminish to a dots. Mature ova diameter ranging from 2 - 42 m.d. (0.022-0.462 mm) (Fig. 87. E, F.).

In *Z. niger* this stage was not encountered during the study period.

Mature ova - spherical, opaque.

iv) Ripe

Ripe ovary was not encountered during the study period for both the species.

2) Testis in *Sufflamen fraenatus* and *Zenodon niger*

The stages identified testes are as follows,

i) Immature

The testes are paired globular structures, white in colour in *Sufflamen fraenatus* (Fig. 86. A).

In *Z. niger* the testes are paired, cylindrical, with a sac having a pore at the basal position (Fig. 86. C).

ii) Mature

Testes are paired, globular or kidney shaped with many small lobes in *Sufflamen fraenatus*.

The paired, cylindrical, testes are slightly larger, having a larger sac at the base in *Z. niger*.

b) Distribution of ova in the ovary

The distribution of ova in the anterior, middle and posterior regions (200 ova from each region was measured) of a mature ovary (222 mm TL) was studied. The percentage frequency distribution of ova of different sizes were calculated. The data pooled from the measurements made in three regions of the ovary (Fig.88.A-C), shows that ova in different stages of maturation are randomly distributed and there is no evidence of concentration of ova of particular size. However, for uniformity, ova were taken only from the middle of the ovary throughout for measurements of ova diameters in each ovary.

1) Development of ova to maturity

i) *Sufflamen fraenatus*

In the immature stage majority of the ova were between 2-8 micrometer division (m.d.) and a mode at 5 m.d. (45%); 40 % of the ova were of 2 - 3 m.d. and 5% ova of 8 m.d.. This immature stock was always recorded in maturing and mature ovaries. The ova in maturing ovary was of 2 - 16 m.d. size range. 36% of the ova were of 4 m.d. size (mode) and 5% of the ova were of 10 m.d. size. In the mature ovary ova were of 2 - 42 m.d. size range, having multiple modes. The first mode is at 6 m.d. (23%) the other modes are at 16, 20, 26, 28, 34, 36 and 40 m.d., which have less than 5 % of ova (Fig. 89.A-C) .

ii) *Zenodon niger*

In the immature ovary of *Zenodon niger,* the ova diameter ranged from 1 to 7 m.d. (0.011-0.077 mm), with the modes at 5 m.d. (45%). In maturing ovary, the ova diameter range from 2 to 20 m.d (0.022-0.22mm) with the mode at 6 m.d. (30%). Mature and ripe ovary was not encountered during the study period (Fig. 90.A & B).

c) Length at first maturity

To determine the size at which *Sufflamen fraenatus* first matures, the condition of the gonads of 252 females comprising of length 166 mm to 290 mm was studied. Figure 91 shows the distribution of these specimens of different length groups (in 5 mm intervals) according to the condition of the gonads. The observation indicates that

specimens in the length range 166-170 and 176-180 were mature (100%) and more than 50 % of the fishes were mature in the length 201–205 onwards.

d) Spawning Period

1) Spawning season

Sufflamen fraenatus

Mature specimens occurred almost throughout the year (table 17). The maximum of 40% of mature specimens in case of *Sufflamen fraenatus* occurred during March followed by September (34%) and November (26.6%).

From the above it can be said that these fishes have a prolonged spawning season from September to March.

Table 17. Monthly percentage frequency distribution of females in different stages of maturity during May 1999- April 2000 in *S. fraenatus.*

Months	Immature (%)	Maturing (%)	Mature (%)	N
May-99	36	56	8	25
June-99	-	-	-	-
July-99	0	81.4	18.5	27
August-99	39.1	56.4	4.3	23
September-99	27.5	37.8	34.4	29
October-99	-	-	-	-
November-99	26.6	26.6	26.6	15
December-99	57.1	35.6	7	42
January-2000	38	61.8	0	21
February-2000	75	12.4	12.4	16
March-2000	48	12	40	25
April-2000	50	42	7	14

2)Gonado-somatic index

Sufflamen fraenatus

This was calculated for both males and females of each individual. The G.S.I. values in males ranged from 0.003 - 0.317 with an average of 0.022. In females G.S.I. values ranged from 0.009 - 3.83 and an average of 0.275. The G.S.I. values estimated indicate an increase with maturity, immature (0.154),

maturing (0.211) to mature (0.750). The monthly average was calculated. From the graph it is evident that in females G.S.I. values were found to be higher during September, November and April. In case of males the G.S.I. values were constant during all the months except during April when it increased (Table 18).

The increase in G.S.I. values indicate development of the gonad, which was during September, November and April (Fig. 92.A).

Table 18. Gonado-somatic index of ***Sufflamen fraenatus***

Sufflamen fraenatus	**Male**	**Female**
May-99	0.2009	0.1752
June-99	-	-
July-99	0.0216	0.3154
August-99	0.0256	0.2312
September-99	0.0211	0.4455
October-99	-	-
November-99	0.0257	0.4747
December-99	0.0137	0.1600
January-2000	0.0183	0.2313
February-2000	0.0179	0.1853
March-2000	0.0248	0.2715
April-2000	0.0499	0.4261

3) Relative condition factor

Sufflamen fraenatus

The relative condition factor (Kn) values were calculated from May 1998 to April 2000 for males and females, employing the formula Kn = w/w^. The average values of each month for both males and females were estimated and plotted in graph (Fig.92.B). The maximum Kn values for male and females were recorded during September, December and April (Table 19).

From the above studies it can concluded that the breeding season of *Sufflamen fraenatus* is prolonged and the peak season is from September to April.

Table 19. Relative condition factor of ***Sufflamen fraenatus***

	Male	**Female**
May	0.9854	1.0136
June	-	-
July	0.9464	0.9975
August	0.9921	0.9844
September	1.0021	1.0679
October	-	-
November	0.9949	0.9877
December	1.0372	1.0398
January	0.9766	1.0171
Febuary	1.0074	1.0141
March	0.9469	0.9846
April	0.9883	1.1051

e) Fecundity

The fecundity estimates were based on 20 specimens of *Sufflamen fraenatus* having a size range of 222 to 286 mm in total length (Table 20). Only the ovaries in mature stages were selected for this study. The number of ova varied from 404 in a fish of 264 mm (TL) to 3,41,516 in a fish of 272 mm (TL), with an average of 62, 205. The relationship between the fecundity and length, weight and weight of ovary found to be insignificant.

Table 20. Relationship between total length, total weight and fecundity

S. No.	TL (mm)	W (g)	Gonad weight	Estimated Fecundity
1	222	298	4.815	122782
2	225	296	0.910	8341
3	233	364	4.328	87684
4	234	366	1.514	8905
5	235	374	5.774	211387
6	235	374	2.566	6155
7	236	350	5.114	78219
8	236	450	11.794	145548
9	238	185	1.141	17160
10	240	360	5.702	136547
11	248	396	2.355	17748
12	255	470	1.678	1204
13	258	470	2.705	13058
14	258	458	1.513	9009
15	258	445	0.592	2525
16	264	480	1.010	6370
17	264	475	0.658	404
18	272	495	0.883	13245
19	272	515	19.772	341516
20	286	560	7.706	16306

3.4.4. Discussion

In *Sufflamen fraenatus* three distinctive stages, immature, maturing and mature were identified and studied based on the external appearance of the ovary and ova. In *Zenodon niger* only ovaries in immature and maturing stages were encountered during the study period.

Nzioka (1979) while making observation of spawning of East African reef fishes has classified the gonads of *Abalistes stellatus* into 3 stages (Inactive, Active and Ripe). Aiken (1983) has classified the gonads of *Balistes vetula* collected from California Bank, south of Port Royal, into three stages (I-inactive, A- active, R- ripe).

Menezes (1985) has applied 5 stages of maturation in case of *Balistes vetula* collected from Brazilian waters. Danson (1990) has also classified gonad of *Balistes capriscus* obtained from coastal waters of Ghana into four stages (Immature, Maturing virgin and recovering spent, Ripe and spent). The wide range of classification in ovary staging in balistids done by the previous worker have clearly brought to the fore that I.C.E.S. system of classification is not possible in these fishes and only three-five main stages can be recognised, they are I-inactive, A- active, R- ripe or immature, maturing virgin and recovering spent, ripe and spent.

The literature on maturation studies on teleosts of temperate and tropical waters clearly suggest that no standard set of stages of maturation can be applied to the ovaries of all oviparous fishes, because maturation cycle of different teleosts vary depending on their habitat and physiological condition. In few of teleosts, seasonal maturation cycles, initiate spawning of ova in a single batch (synchronous ovary), as in the case of Herring (Hickling, 1930), where as in some, mature ova may be released in two or more batches (asynchronous ovary). The synchronous ovary consists of at least two size groups of oocytes, with mature oocytes being more homogenous. In asynchronous ovary, oocytes in all stages of development are present (West, 1990). Most of the tropical fishes have a prolonged breeding season and these fishes possess several batches of eggs destined to be matured and shed periodically (Qasim, 1973). Thus, the stages of maturity as applied to Herring (Wood, 1930) is not appropriate to tropical fishes, which are fractional spawners. Considering the overall implications of the problem related to quantification of maturity Qasim (1973) feels that in tropical and subtropical forms, the classification of gonads should only be limited to about 5 maturity stages (I. Immature, II. Maturing virgins or recovered spents, III. Ripening, IV. Ripe, V. Spent) and in continuous spawners it may be reduced from 5 to 3 (I. Immature, II. Maturing, and III. Ripe). But Prabhu (1956) is of the opinion that the staging based on the ova of the ovary, in the tropical fishes can be classified to 4 stages (I. Immature ova, II. Maturing ova, III. Mature ova, III. Ripe ova). This method (4 Stages) was found to be most suitable and appropriate for *Sufflamen fraenatus* and *Zenodon niger,* which possess asynchronous ovary.

The ripe ovary in *Sufflamen fraenatus* and mature and ripe ovary in *Zenodon niger* were not encountered during the period of study.

According to Gladstone (1994) among the coral reef fishes, trigger fishes display pre-courtship, courtship and parental care behaviour at the time of spawning (Authors has made a direct observations by SCUBA diving). Two types of spawning have been recorded in these fishes, "Lek- type" and "Haremic type". In Lek- type the trigger fishes migrate to a traditional mating ground where the male establish a territory and builds a nest with an egg chamber. The male attracts a single female from a school by fin displays. The spawning takes place in the nest and the fertilized eggs are deposited in the egg chamber and guarded by both the parents (Gladstone, 1994). According to Kuwamura (1997), in *Rhinecanthus aculeatus* (monogamous or polygamous) one or two female territory falls under a dominant male territory, the former makes the nest and guards the fertilized eggs. Lobel and Johannes (1980) recorded nest building in *Pseudobalistes flavimarginatus* and *Balistapus undulates* on the sandy bottoms or in the channels of the fringing reef at Palau, western Caroline Islands or barrier reef at Fanning Atoll. The eggs are laid on the sand nests made by the females, which are having 0.7 m diameter. According to Fricke (1980) fishes of the family Balistidae display some peculiar behaviour at the time of spawning. The observations were made on the spawning behaviour of *Peudobalistes fuscus* and *Odonus niger* at Gulf of Akaba in Red sea. *Peudobalistes fuscus* lives in shallow part of the reef area, which has a coral coverage of 5-10%. The bottom is hard beach rock with patches of coarse coraline sand. Female initiates the courtship before sunset by blowing the sand and making a nest pit. The female lays the eggs and guides the male to the nest pit, to fertilize the eggs. In case of *Odonus niger* communal type of courtship occur during summer in the coral knolls on the sandy slopes slightly away from there sleeping hole (Lek type). In a group of 13-16 females only a single male is present. The females build the nest and lay eggs during early morning, which the male fertilizes. Aiken (1983) is of the opinion that *Balistes vetula* might move to deeper waters on maturation as most of specimens caught from the Port royal reef were small and maturing individual. The observations made by Kawase and Nakazono (1992) show that *Sufflamen chrysopterus* at Kashiwajima, southern Shikoku, Japan, lives on the sandy slope with patch of reefs and scattered boulders, pairing takes place and female builds the nest in the sandy bottom by making a pit. The sticky eggs are laid at early morning and fertilized by the male. From the above observations it can be concluded that balistids have peculiar spawning behaviour which includes pre - courtship "nest building activity", courtship "pairing with opposite sex and Parental

care "guarding the egg". This activity takes place at sandy slope having corals or at the edge of fringing reef or barrier reefs having sandy area or channels.

Thus it may be concluded that the ripe fishes in case of *Sufflamen fraenatus* and mature and ripe fishes in *Zenodon niger* were not recorded during the study, because the materials for study were collected from the trawlers and small mechanised boats which operate hooks and lines. Most of the fishing activity by trawlers takes place on the sandy grounds (without corals and rocks). Hooks and line are operated in areas about 5 – 10 km from the shore. These areas may not be the breeding grounds of these fishes and this may be the reason for not getting ripe fishes. It is possible that these fishes have specific areas (coral reefs as mentioned by Lobel and Johannes (1980), Fricke, (1980) Kawase and Nakazono (1992)) for spawning, which they occupy prior to the time of spawning (which last for a day or two) and then migrate back to its territory. In case of *Sufflamen fraenatus* the above said possibility has been supported by samples collected from cruise 3B of FORV *Sagar Sampada,* which consists of young ones of *Sufflamen fraenatus* having a length range of 15-30 mm (More than 500 numbers) collected by Isaac-Kidd Midwater Trawl (IKMT) off Cochin (10° 30' N – 73° 00' E) , which clearly indicates that these fishes breed far from the shore in the coral banks (Anon, 1986).

Sufflamen fraenatus has a prolonged breeding season and most of the females are in mature condition from September to April.

Nzioka (1979) has stated that ripe specimens of *Abalistes stella*tus were encountered during March, August, September and October at East African reef. Aiken (1983) has recorded ripe specimens of *Balistes vetula* throughout the year except April and June. In case of *Canthidermis maculates* ripe fishes were encountered during January, May, August, September and December with maximum in September. In *Melichthys niger* ripe fishes were encountered in March and August and November. In *Xanthichthys ringens* ripe fishes occurred during March and November at California Bank, Port Royal reef. Danson (1990) while studying *Balistes capriscus* of Ghanaian coast has defined the spawning season from October to December.

A direct comparative study on *Sufflamen fraenatus* cannot be made as the information regarding the spawning seasons of these fishes from other part of the world is not available but details of the spawning seasons of other balistids clearly indicates that these fishes have prolonged spawning season and they have specialised spawning behaviour. Most of the observations are based on the availability of ripe fishes at the place of study. Thus from the observations made by earlier worker agrees with the present finding.

The ova diameter study shows that there are three types of ova (immature maturing and mature) in the mature ovary of *Sufflamen fraenatus.* The ova diameter ranged from 2 – 42 m.d. and had multiple modes. The mode of the immature ova had 23% of the ova. Other modes consist of maturing and mature ova, which have less than 5% of ova. In case of *Zenodon niger* the maturing ovary had ova having a diameter range of 2 – 16 m.d. with a mode of immature ova.

Observations of ova diameters study of balistids are not available but the fertilized egg collected from the nest of some of the balistids like *Balistapus undulates* and *Pseudobalistes flavimarginatus* have a diameter of 0.55 mm (Lobel and Johannes, 1980). According to Kawase and Nakazono (1992) the eggs of *Sufflamen chrysopterus* collected from the nest are of the adhesive type having a diameter of 0.75mm.

The objective of ova diameter study is to make an estimate on the number of times a fish spawns. According to Hickling and Rutenberg (1936), Walford (1932), De Jong (1940) the spawning activity in fishes may be classified into 4 categories,

A- Spawning taking place only once a season during a short period of definite duration. In fishes belonging to this category, the mature ovary contains mature ova distinctly separated from the immature egg stock.

B- Spawning taking place only once a season, but with a longer duration. In species exhibiting this type of spawning, the range in size of the mature ova, irrespective of the number of modes representing them has been found to be nearly half the total range in size of the entire intraovarian eggs.

C- Spawning twice a year. In the ovaries of fishes exhibiting this type of spawning, in addition to the batch in ripe condition, another batch of eggs, which has undergone more or less half the process of maturation, becomes apparent.

D- Spawning extends over a long period, but intermittently. Here the different batches of eggs in the ovary are not sharply differentiated from one another, thereby indicating that the passing of one batch of eggs into the next stage is a continuous process.

The data on ova diameter of *Sufflamen fraenatus* clearly shows that this fish appears to belong to the category 'D'. The presence of multiple modes of ova in the mature ovary clearly suggests that the fish spawns continuously. One large mode of immature ova and one mode of maturing ova and five modes of mature ova clearly indicates that in *Sufflamen fraenatus* the ovary after releasing the batch of ripe ova, returns to the mature stage (mature ovary). The fact that a group of mature ova follows the other mature group shows that another spawning takes place soon; naturally yet another group of mature ova will follow this, as the withdrawal of eggs is in batches for undergoing maturation and that is a continuing process. James and Baragi (1980) made similar conclusions, after studying the ova-diameter frequency distribution of three marine fishes.

At 166 mm *Sufflamen fraenatus* is mature and 50% of the fishes mature in the length range of 201–205 mm (TL).

According to Aiken (1983) the minimum size at first maturity of males in *Balistes vetula* is 175mm fork length (FL) and females attained maturity at a minimum size of 165 mm (FL). The mean size at maturity in this fish is found to be 265 mm (FL). In *Balistes capriscus* the estimated size at first maturity is 145 ± 12 mm (FL) and adult female attained a minimum size 133 mm (FL) at first maturity.

The above said study clearly suggests that the minimum size at first maturity in balistids range from 133 to 175 mm (FL) and the results from the present study have similar range of length.

The estimated fecundity of *Sufflamen fraenatus* having a length range of 222-286 mm (TL) varied from 404 in a fish of 264 mm (TL) to 3,41,516 in a fish of 272 mm (TL), with an average of 62,205.

Lobel and Johannes (1980) while examining the cluster of eggs laid by *Pseudobalistes flavimarginatus* has estimated the number of eggs to be 4,30,000. A study made by Kawase and Nakazono (1992) on the egg mass of *Sufflamen chrysopterus* calculated the total number of eggs to be 1,32,800.

Aiken (1983) have estimated the fecundity of some of Balistids available in the Port Royal reef, according to him *Balistes vetula* having a total length of 280 –370 mm had an estimated number of eggs in the range of 49,000 – 83,000, *Canthidermis Sufflamen* having a total length of 387 –501 mm had an estimated number of eggs in the range of 2,19,700 – 6,20,000. Menezes (1985) states that *Balistes vetula* of Brazilian coast have an estimated fecundity of 8,915 – 64,422 in fishes having a size range of 269 - 321mm.

The observations of previous workers and the observations made from the present study clearly indicate that the fishes of the family Balistidae have high fecundity.

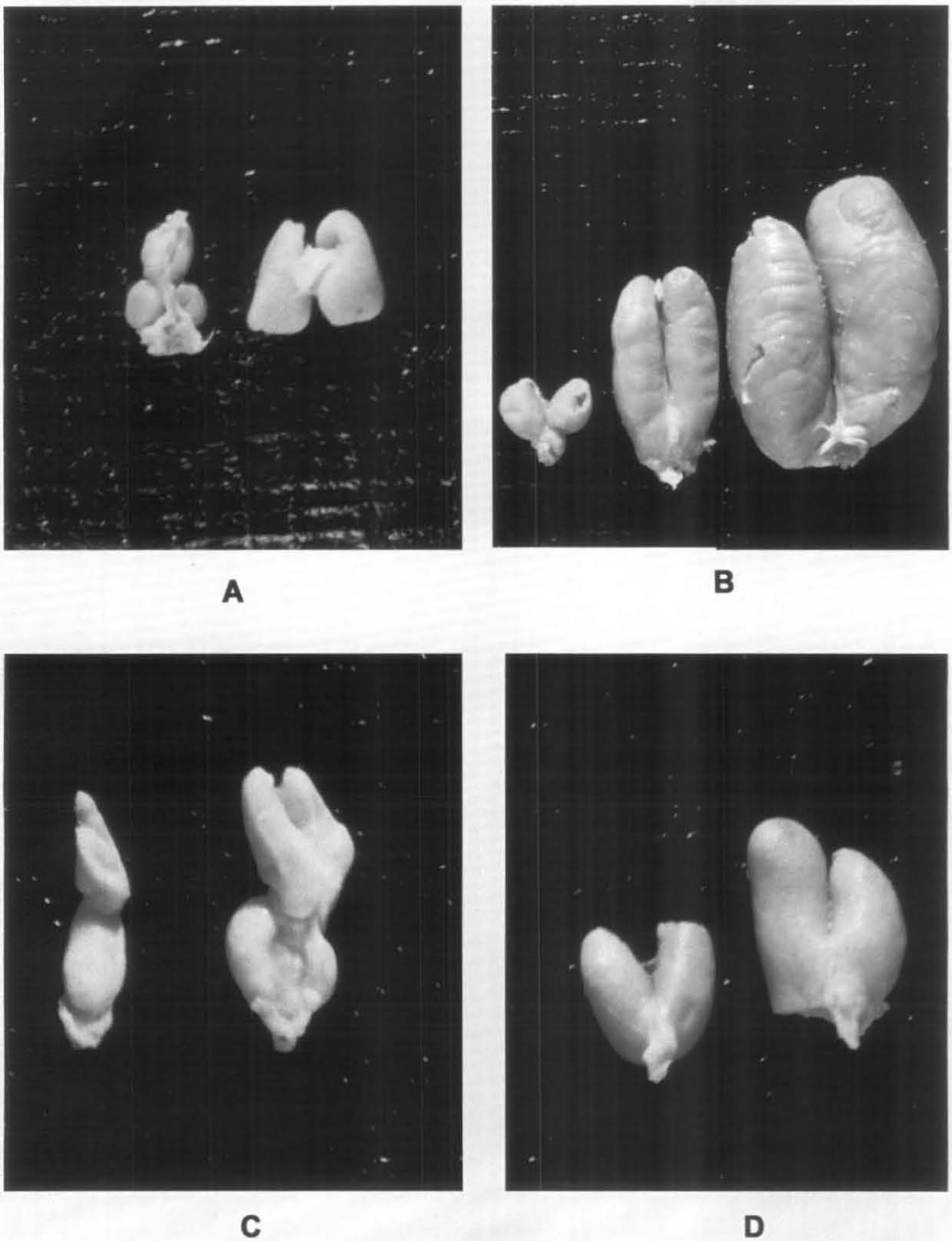


Figure 86. A. Immature and mature testis of *Sufflamen fraenatus.* B. Immature, maturing and mature ovary of *Sufflamen fraenatus*. C. Immature and mature testis of *Zenodon niger.* D. Immature and maturing ovary of *Zenodon niger*

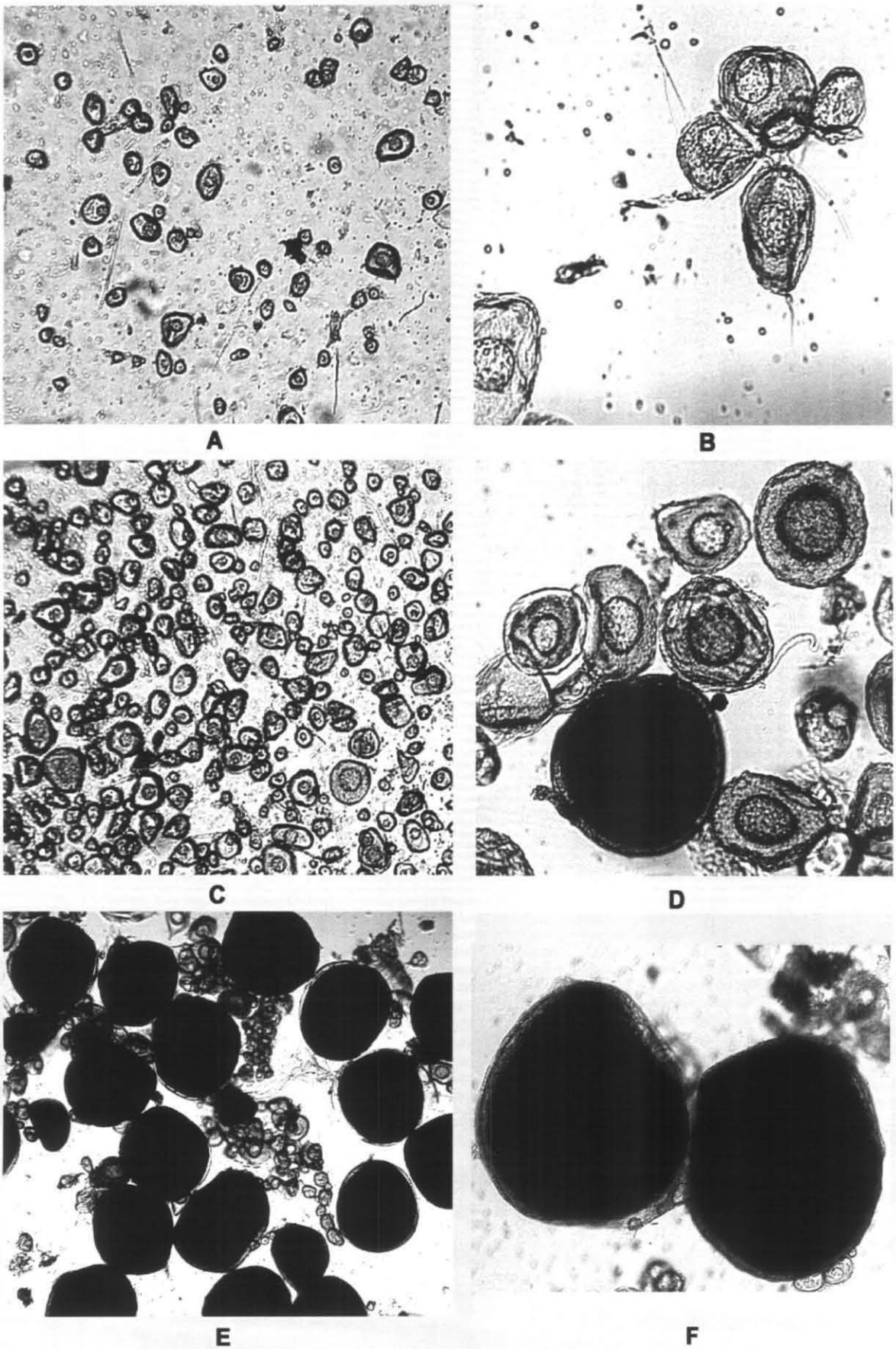


Figure 87. Ova of *Sufflamen frenatus*: A. Immature ova (40x). B. Immature ova (100x). C. Maturing ova (40x). D. Maturing ova (100x). E. Mature ova (40x). F. Mature ova (100x).

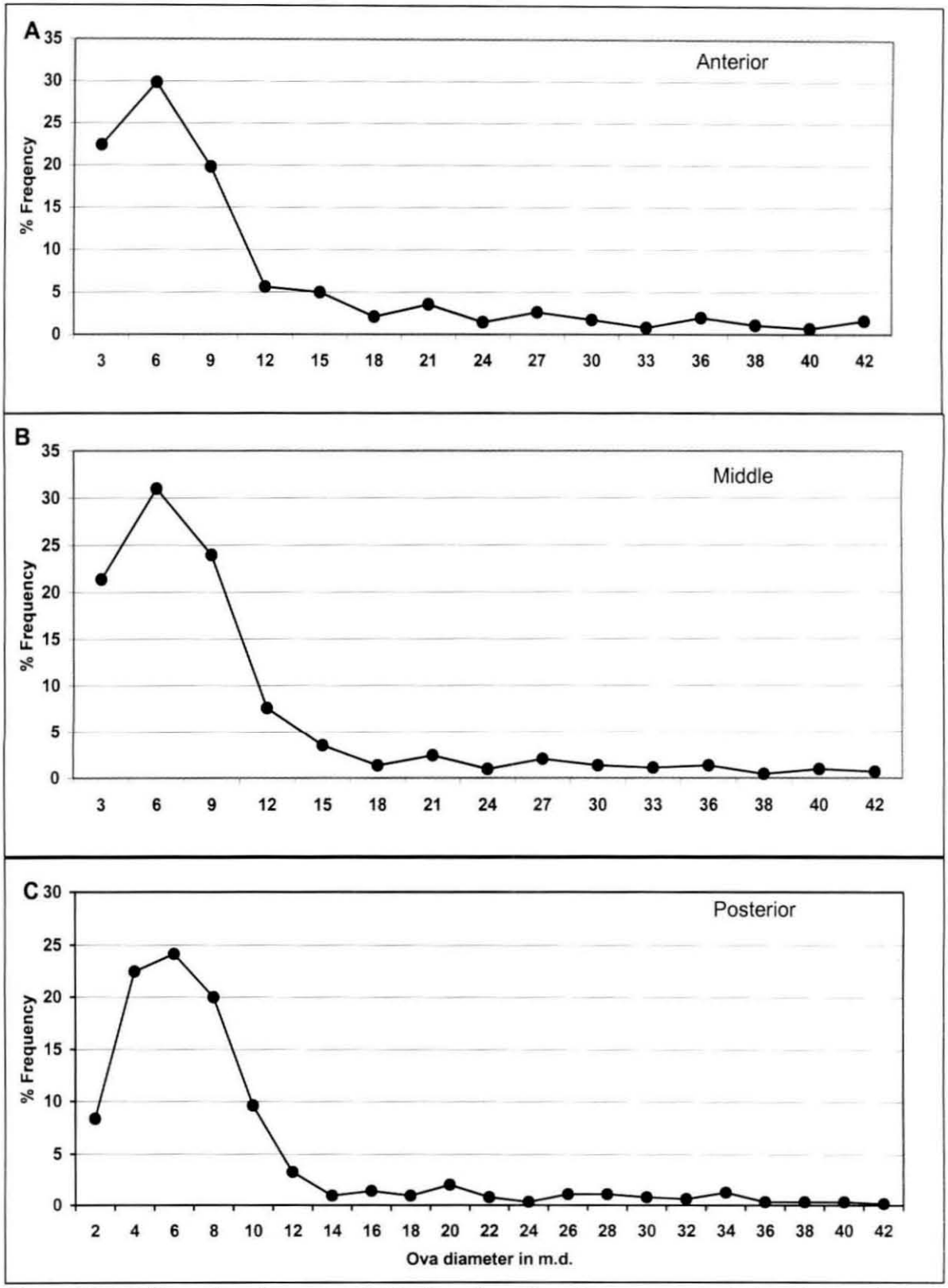


Figure 88. A-C Percentage frequency distribution of ova diameter measurements in anterior, middle and posterior portion of the ovary of *Sufflamen fraenatus*

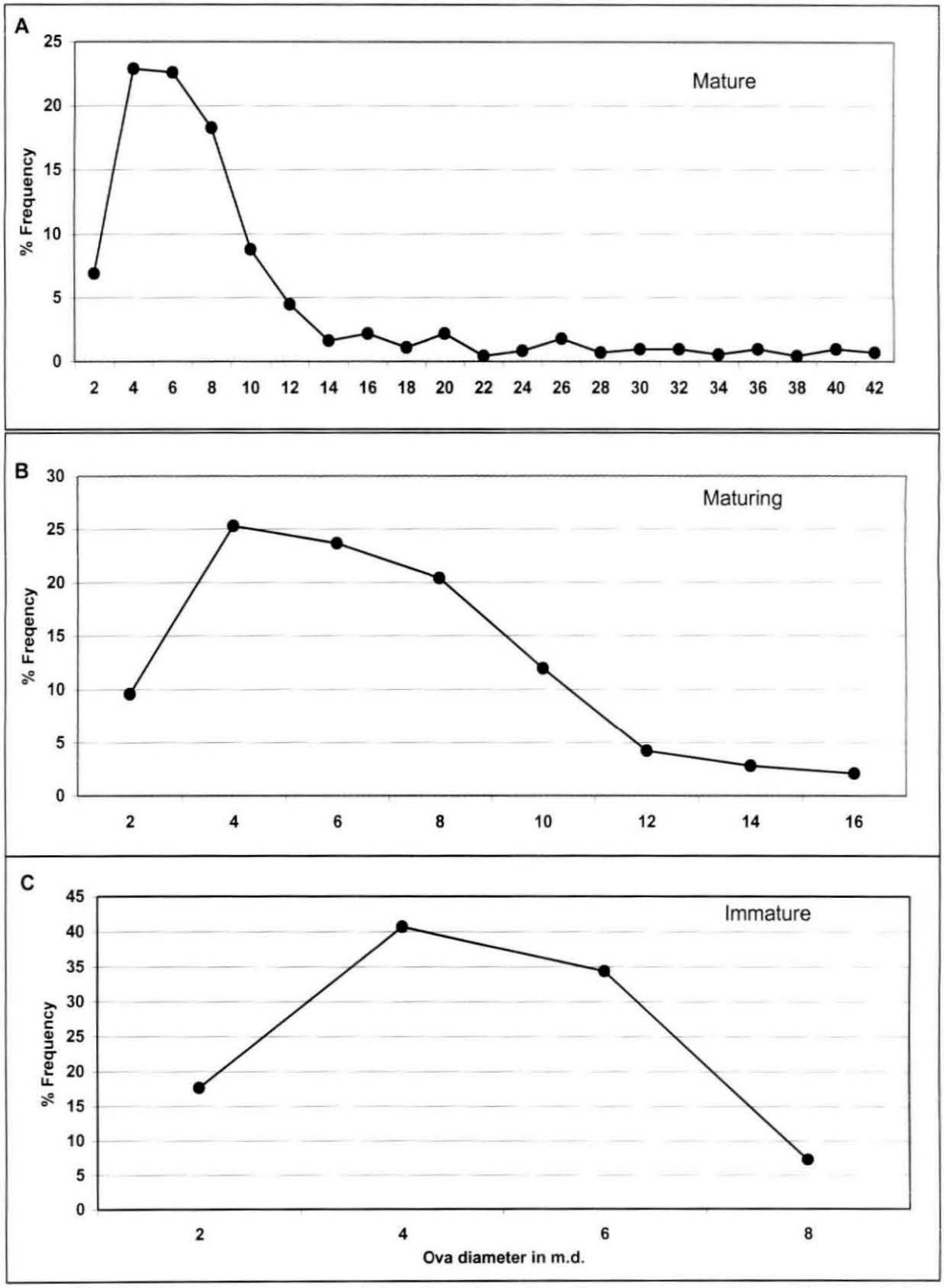


Figure 89. A-C Percentage frequency distribution of ova diameter measurements in mature, maturing and immature ovary of *Sufflamen fraenatus*

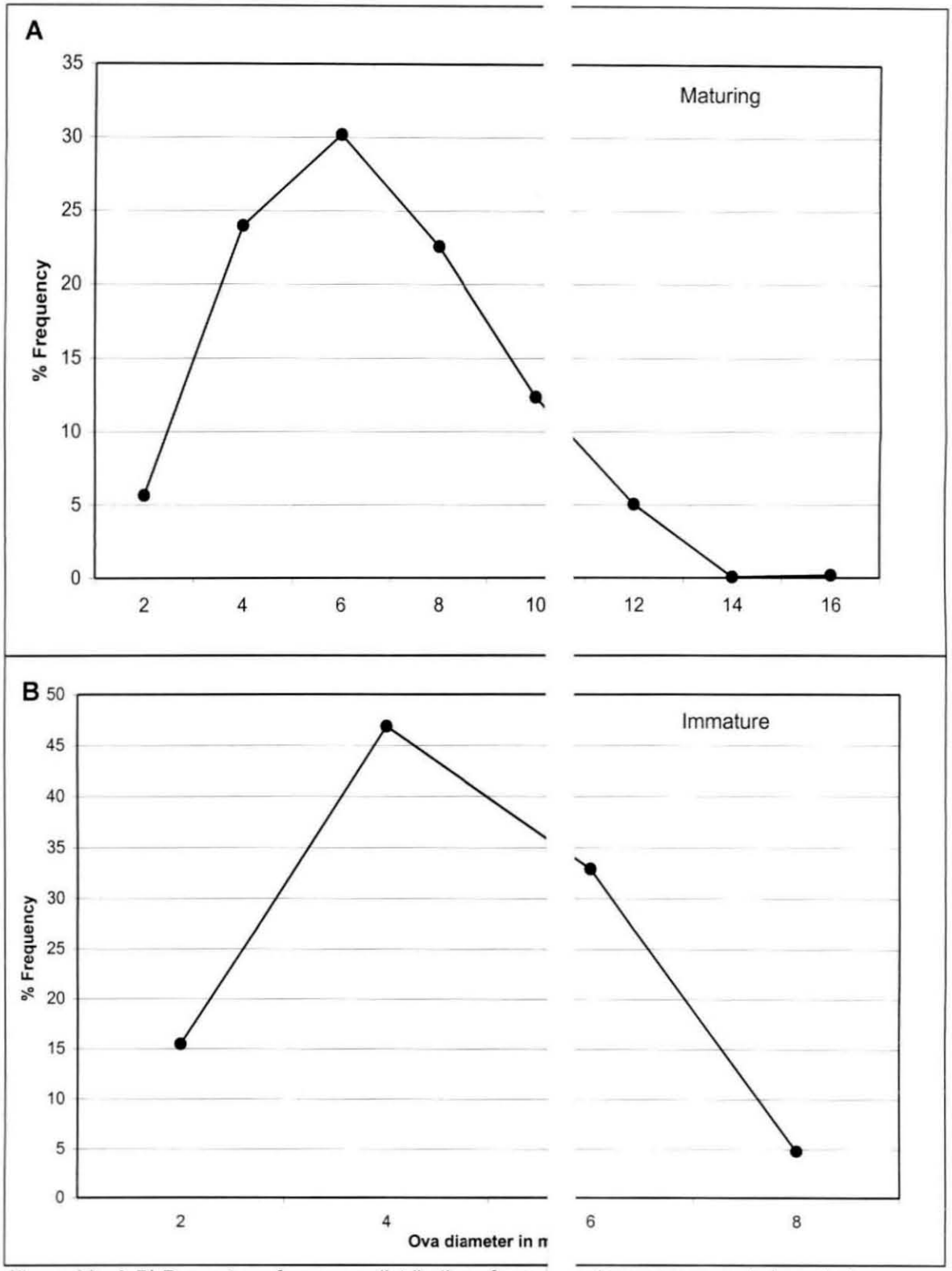


Figure 90. A-B) Percentage frequency distribution of ova d neter measurements in maturing, Immature ovary of *Zenodon niger*

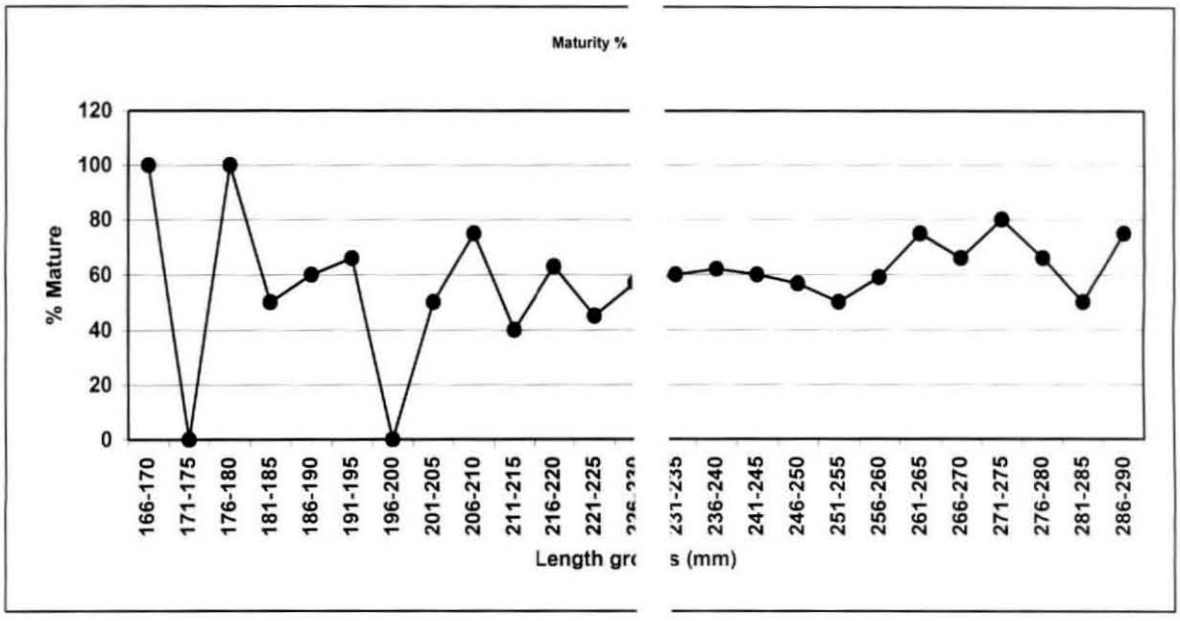


Figure 91. Percentage of mature female fish in *Su men fraenatus*

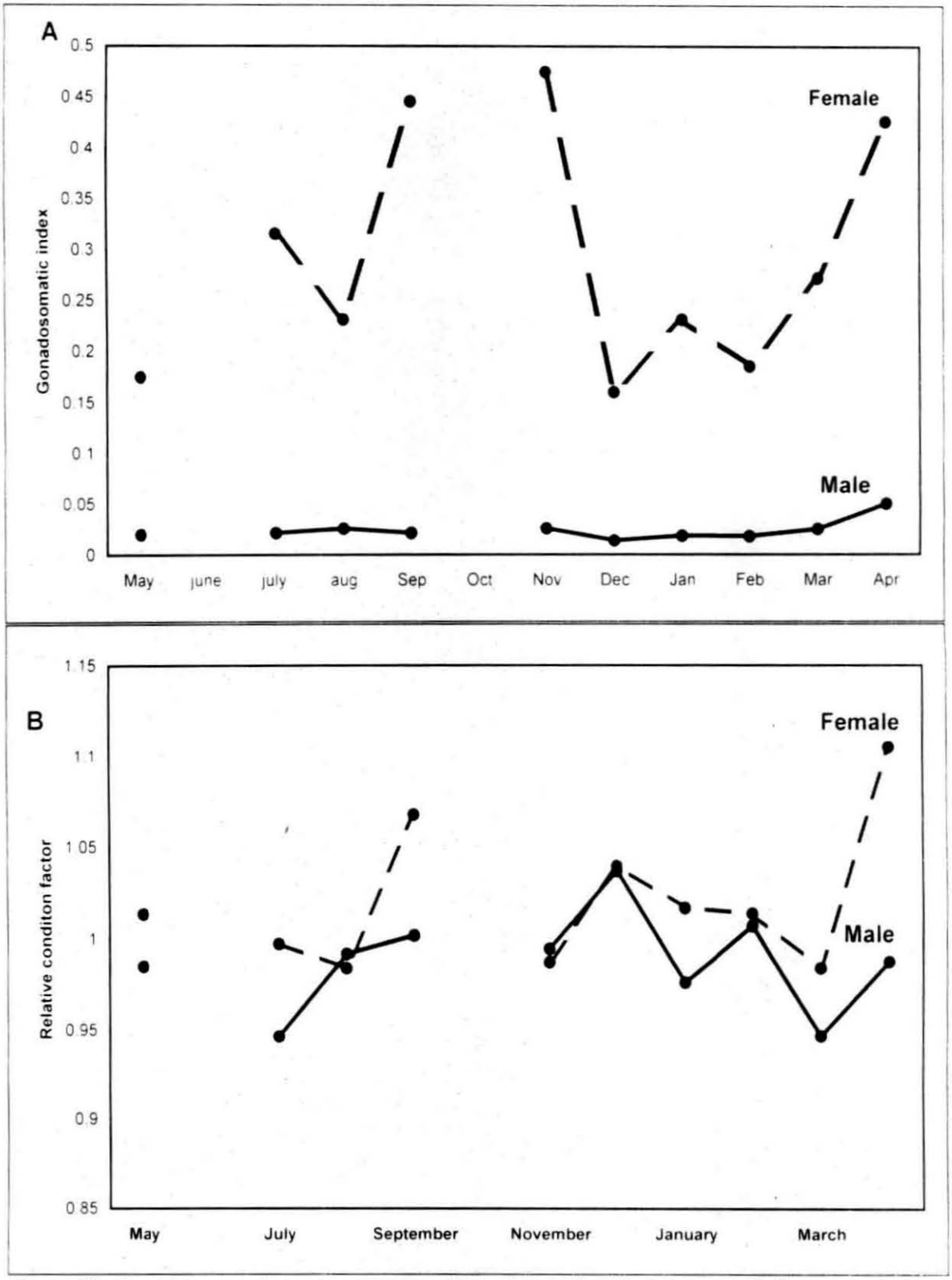


Figure 92 A) distribution of monthly average values of gonado-somatic index in *Sufflamen fraenatus*
B) The relative condition factor in *Sufflamen fraenatus*

Summary

1. Samples of fishes of the family Balistidae were collected regularly from landings of hook and line and trawl at Tuticorin and Kanyakumari along southeast coast of India; Vizhinjam and Colachel along southwest coast of India during August 1998 to October 2000. Specimens of a few species were collected from trawl, trap, spear, gill net and hook and line landings of Mumbai, Veraval, Chennai, Mandapam and Kelakarai and Minicoy Island (Lakshadweep) were also analysed for this work. Specimens in the collections of Zoological Survey of India (ZSI), Kolkatta and those in the reference collection Museum of the Central Marine Fisheries Research Institute (CMFRI) at Cochin and Mandapam were also examined.
2. The morphological characters like teeth, nasal apertures, gill rakers were studied.

3. Based on the shape of the first and second teeth of the upper and lower jaw, five types have been identified.

4. The anterior nasal aperture has different shapes, which is species specific but the posterior aperture is similar in all species. Based on the shape of the anterior nasal aperture five types have been identified.

5. The outer most branchial arch possesses gill rakers. Based on its shape they are divided into five types.

6. The pattern of arrangement of scales and its eternal morphology was studied.

7. Scales on body and caudal peduncle are diamond shaped, were as scales on cheek are rhomboid, rectangular, square or triangular occurring in different combinations. Scales on abdomen are rhomboid or rectangular or square with round edges.

8. The arrangement of scales on body, abdomen and caudal peduncle were similar between the species.

9. The scales arranged in three patterns on cheek.

10. Scales on cheek are of 7 types based on shape of the scale and type of protuberances it possessed on the posterior margin.

11. Body scales are of five types.

12. Scales on abdomen are of three types.

13. The scales on caudal peduncle are of five types.

14. The transverse section of body scales under the scanning electron microscope revealed that the scale consists of 4 layers.

15. The studies on the ultra structure of the anterior margin of the body scales revealed that there are 5 types, based on the type of protuberances it possesses and the posterior margin are of four types.

16. The taxonomic study on fishes of the family Balistidae reveal that:

17. In *Balistapus undulates* (Mungo Park, 1797) the colour pattern varies according to length.

18. The genus *Odonus*, Gistel 1848 previously accepted as the replacement name for genus *Xenodon*, Ruppell 1835 has been presently replaced with *Zenodon* (Ruppell, 1835) Swainson, 1839.

19. The genus *Rhinecanthus* has been redefined.

20. *Melichthys niger* identified by Jones and Kumaran (1980) appears to be a synonym of ***Melichthys*** *indicus* Randall and Klausewitz, 1973, on the available evidence.

21. *Canthidermis willughbeii,* ***C. rotundatus,*** *C.* ***villosus*** described by Fedoryako (1981) appears to be synonyms of *C. maculatus* on available evidence.

22. *Parabalistes* Bleeker 1866 has been resurrected to a valid genus.

23. *Pseudobalistes viridescens* (Bloch and Schneider, 1801) and *Pseudobalistes flavimarginatus* (Ruppell, 1828) showed variations in the colour pattern.

24. *Sufflamen fraenatus* (Latreille, 1804) is believed to be similar to *Sufflamen verres,* Gilbert and Stark 1904 on available evidence.

25. Key to identify the genera of family Balistidae are given.

26. Key to identify the species of fishes of the family Balistidae of India based on the scales are given.

27. **The results of the biological studies on *Sufflamen fraenatus* (Latreille, 1804) and *Zenodon niger* (Ruppell, 1835) revealed that:**

28. The length-weight relationship of *Sufflamen fraenatus* (Latreille, 1804)

$$\text{Log } W = -9.0429 + 2.7296 \log L$$

$$\text{or} \quad W = 0.000000000905 * L^{2.72776}$$

$$R^2 = 0.9301$$

29. The length-weight relationship of *Zenodon niger* (Ruppell, 1835)

$$\text{Log } W = -6.507 + 2.085 \log L$$

$$\text{or} \quad W = 0.0000003117 * L^{2.08556}$$

$$R^2 = 0.6749$$

30. In *Sufflamen fraenatus* three distinctive stages, immature, maturing and mature were identified and studied based on the external appearance of the ovary and ova.

31. In *Zenodon niger* only ovaries in immature and maturing stages were encountered during the study period.

32. In *Sufflamen fraenatus* there are three types of ova (immature, maturing and mature), in the mature ovary having a diameter ranging from 2 – 42 m.d. with multiple modes.

33. In case of *Zenodon niger* there are two type of ova in the maturing ovary having a diameter range of 2 – 16 m.d. with a single mode.

34. *Sufflamen fraenatus* has a prolonged breeding season and most of the females are in mature condition during September to April.

35. In *Sufflamen fraenatus* 50% of the fishes were mature in the length range of 201–205 mm (TL).

36. The estimated fecundity of *Sufflamen fraenatus* having a length range of 222-286 mm (TL) varied from 404 in a fish of 264 mm (TL) to 3,41,516 in a fish of 272 mm (TL)

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